Older Age Increases Short-term Surgical Complications After Primary Knee Arthroplasty

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Abstract

Background Age is a known risk factor for complications after knee arthroplasty; however, age-related risks for a variety of complications of total and partial knee arthroplasties have not been well quantified.

Questions/purposes Our study addressed three questions to better understand age-related risk of complications: (1) At what age do different types of complications increase? (2) Is the increase in complications with age resulting from age-related patient comorbidities, socio-demographic characteristics, and surgical conditions? (3) What is the probability of complications at different ages for an average patient?

Methods The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP)

database from 2005 to 2009 was used to analyze complications for 8950 patients. Complications included NSQIP events, and complications described by the 2003 National Institutes of Health (NIH) consensus statement on total knee arthroplasty as well as 30-day mortality, deep vein thrombosis, return to the operating room, extended length of stay, and technical aspects of the surgery itself. Logistic regression analysis was performed.

Results Mortality was higher for those aged 85 and older. NSQIP complications increased starting at age 70 years and NIH complications at 85 years. Age remained an independent risk factor for multiple complications with controls. The predicted risk for an average patient ranged from 4% (40–64 years old) to 17% (90 years or older) for NSQIP complications and 2.8% to 8.8% for NIH complications.

Conclusions Age is an important independent predictor of surgical complications after knee arthroplasties. Surgeons can share these quantified age-specific risks with patients to guide management decisions.

Level of Evidence Level I, prognostic study. See Instructions for Authors for a complete description of levels of evidence.

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Introduction

TKAs are among the most common elective surgical procedures performed in the United States today, with more than half a million procedures performed annually [16, 21]. Most of these procedures are performed in the geriatric population, which is estimated to grow from 13% of the US population in 2009 to 19% in 2030 [26]. While the population is aging, developments in medicine and public health have led to older persons leading longer and healthier lives.

As a result, elective operations are an increasingly important part of health care for the elderly, and they are being performed on older patients. Older individuals may suffer from more complications as a result of physiologic changes related to aging itself such as deterioration of the immune system, decreased ability to withstand the trauma of surgery, and vascular deterioration; another possibility is that increased surgical morbidity is the result of higher incidence of comorbidities in older patients [6, 13, 14, 19, 20]. Because knee arthroplasty is increasingly more common among older patients, there are several important questions regarding TKA complications.

TKA is associated with more complications and higher mortality at older ages [8, 9, 17, 22–24]. However, previous clinical studies have been limited by small sample sizes [8, 9, 17], heterogeneous patients and outcome measures [22], and subjective aspects of data collection [9, 23]. Most importantly, age as a continuum has not been investigated as an independent risk factor [21] for a comprehensive and uniform set of complications [5, 8, 24]. Therefore, differences in risk across older ages are unclear. For instance, some studies do not distinguish within old age so 65 year olds and 85 year olds are not examined separately [17, 24]; and existing studies do not have large enough samples of very old patients that allow clarification of the independent effect of age once comorbidities have been simultaneously considered. Smaller sample sizes are particularly a problem for rare events like mortality [3, 8, 9, 11, 22]. In addition, the existing literature does not provide an approach to estimating the probability of complications for people of different ages and with different comorbidities.

The purpose of the present study was to answer three questions surrounding short-term (eg, 30-day) postoperative morbidity and mortality: (1) At what ages do different types of complications increase? (2) Is the increase in complications with age the result of age-related patient comorbidities, sociodemographic characteristics, and surgical conditions? (3) What is the probability of complications at different ages for an average patient?

Patients and Methods

We explored a widely used national database that is prospectively maintained by the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) [1, 10]. The NSQIP is a nationally validated, outcome-based program to measure and improve the quality of inpatient and outpatient surgical care and the details of the NSQIP program are readily available [1, 10]. Trained Surgical Clinical Reviewers at participating institutions collect, validate, and submit data. The data contain information on each patient collected on an inpatient and outpatient basis.

Internal audits ensure high-quality data with low interobserver variability. The NSQIP database has strict definitions for complications that occur within 30 days of surgery such as deep vein thrombosis or myocardial infarction. The database also includes information on patient demographics (ie, age, sex, race), preoperative comorbidities (ie, diabetes mellitus), operative variables (ie, type of anesthesia used), and postoperative information (ie, 30-day mortality) [2].

We analyzed knee arthroplasty procedures performed between 2005 and 2009. In 2009 the cases originated from 237 participating hospitals [1]. For this study, we examined 9001 patients receiving partial or TKAs as identified by Current Procedural Terminology (CPT) codes 27446 and 27447; 271 patients undergoing revision knee arthroplasty (CPT codes 27486, 27487) were not included in this study. Fifty patients younger than 40 years and one patient receiving an additional operative procedure at the same time were excluded. These 51 exclusions left 8950 patients. The data set was deemed exempt from institutional review board review, because the data source does not contain individual patient identifiers.

The median age of our sample was 67 years with approximately 40% of patients younger than 65 years, 18% 65 to 69 years, 31% 70 to 79 years, 11% 80 to 89 years, and 0.6% older than 90 years (Table 1). Approximately two-thirds of patients were female, and 80% were non-Hispanic whites. Almost 90% of patients were overweight or obese with 28% in the overweight category and 61% in the obese category. The prevalence of most comorbidities was less than 10% with the exception of hypertension (70%), diabetes (18%), and dyspnea (11%). Fifty-two percent of the patients received general anesthesia.

We analyzed seven complications derived from the NSQIP database as outcome measures; these represent the dependent variables in our analysis (Table 2). We analyzed four specific postoperative complications: 30-day mortality, extended length of stay (defined as > 7 days), return to the operating room, and deep vein thrombosis (DVT) requiring treatment. In addition, we grouped complications from the NSQIP database three ways to define other outcome measures (Table 2). One measure (referred to as “NSQIP complications”) consisted of the entire group of postoperative complications recommended by the ACS for inclusion in the NSQIP database that occurred within 30 days of operation. This is the most comprehensive measure and includes complications relevant for multiple types of surgeries [7, 10]. Another measure (referred to as “NIH complications”) consisted of the NSQIP complications deemed to be primary complications of TKA by the 2003 National Institutes of Health Consensus Statement on Total Knee Replacement [15]. This set eliminated some of the severe complications that might be related to age such

Table 1. Descriptive statistics for independent variables

Variable*	Frequency	Percentage
Age (years) (n = 8950)		
40–64	3603	40.3
65–69	1579	17.6
70–74	1492	16.7
75–79	1266	14.2
80–84	701	7.8
85–89	258	2.9
≥ 90	51	0.6
Race (n = 8523)		
Non-Hispanic white	6809	79.9
Non-Hispanic black	640	7.5
Hispanic	854	10.0
Asian, Pacific Islander, Native Hawaiian	168	2.0
American Indian or Alaska Native	52	0.6
Sex (n = 8950)		
Male	3194	35.7
Female	5756	64.3
Body mass index (kg/m ²) (n = 8877)		
< 18.5	41	0.5
18.5–24.9	912	10.3
25–29.9	2509	28.3
30–34.9	2500	28.2
35–39.9	1626	18.3
≥ 40	1289	14.5
Comorbidities (n = 8950)		
Diabetes	1646	18.4
Current smoker within 1 year	810	9.1
Current high alcohol use	194	2.2
Dyspnea	949	10.6
History of severe COPD	347	3.9
CHF within 30 days of surgery	17	0.2
Previous PCI	569	6.4
Previous cardiac surgery	418	4.7
History of angina within 1 month	59	0.7
Hypertension requiring medication	6278	70.2
History of PVD	65	0.7
Paraplegia	47	0.5
Open wound or wound infection	40	0.5
Steroid use for chronic condition	226	2.5
Bleeding disorder	257	2.9
Preoperative sepsis	37	0.4
Stroke	499	5.6
Prior operation within 30 days (n = 8910)	28	0.3
Dependent status (n = 8950)	314	3.5
Year of operation (n = 8950)		
2005–2006	172	1.9
2007	977	10.9
2008	2810	31.4

Table 1. continued

Variable*	Frequency	Percentage
2009	4991	55.8
Nongeneral anesthesia (n = 8950)	4273	47.7
Emergency case (n = 8950)	32	0.4

* Definitions of variables: current high alcohol 1 = ≥ 2 drinks/day in the 2 weeks before admission; dyspnea = difficult, painful, or labored breathing at rest or on exertion; history of CHF = CHF diagnosed within 30 days of surgery or presenting with new signs or symptoms within that period; PCI = previous percutaneous coronary intervention including balloon dilatation or stent placement; previous major cardiac surgery = either off-pump or with cardiopulmonary bypass; steroid use = regular parenteral or oral corticosteroid use for a chronic medical condition, preoperative systemic sepsis = includes systemic inflammatory response syndrome, sepsis, and septic shock; previous stroke = includes transient ischemia attacks and cerebrovascular accidents with or without neurologic deficit; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease.

as renal failure and stroke. “Orthopaedic complications” contained the NSQIP complications more likely to result from technical aspects of a surgery itself (surgical site infections, wound dehiscence, peripheral nerve injury, implant failure).

For each of these three groups of complications, if an individual experienced one or more of the specific complications within the group definition, then the patient was considered to have experienced the complication (ie, an “NIH complication” or an “orthopaedic complication”). We report whether or not a complication event occurred. Like the NSQIP database, in reporting the information, we did not attempt to make a judgment about whether one type of complication implied greater morbidity than another. The frequency of complication data is presented (Table 3).

The 30-day mortality rate was 0.12% (Table 3). Six percent of patients experienced one of the NSQIP complications, 3.9% one of the NIH complications, and 1.5% one of the orthopaedic complications within 30 days of the operation. Approximately 1.5% of patients had a DVT, 1.7% returned to the operating room within 30 days, and 3.3% experienced an extended length of stay. Individual complications that comprise the composite indices occurred at a frequency of less than 1%, except for urinary tract infection (1.6%); the occurrence of pulmonary embolism was 0.76%.

To address our first question of clarifying the precise age group at which different types of complications increase significantly, we performed multivariate logistic regressions with age categories for the seven dependent variables: 30-day mortality, NSQIP complications, NIH complications, orthopaedic complications, DVT, return to operating room, and extended length of stay. Odds ratios significantly

Table 2. Thirty-day complications described in the NSQIP database and used in the outcome variables

Complication	NSQIP	NIH	Orthopaedic
Infectious/wound complications			
Superficial incisional surgical site infection	✓	✓	✓
Deep incisional surgical site infection	✓	✓	✓
Organ/space surgical site infection	✓	✓	✓
Wound disruption	✓	✓	✓
Pulmonary complications			
Pneumonia	✓	✓	
Unplanned intubation	✓		
Pulmonary embolism	✓	✓	
Failure to wean off ventilator	✓		
Renal complications			
Progressive renal insufficiency	✓		
Acute renal failure	✓		
Urinary tract infection	✓		
Neurologic complications			
Stroke/CVA with neurologic deficit	✓		
Coma of longer than 24 hours	✓		
Peripheral nerve injury	✓	✓	✓
Cardiac complications			
Cardiac arrest requiring CPR	✓		
Myocardial infarction	✓	✓	
Other complications			
Postoperative blood transfusion	✓		
Prosthesis failure	✓	✓	✓
DVT requiring therapy	✓	✓	
Sepsis	✓		
Septic shock	✓		
30-day mortality			
Return to operating room			
Extended length of stay			

NSQIP = National Surgical Quality Improvement Program; NIH = National Institutes of Health; CVA = cerebrovascular accident; CPR = cardiopulmonary resuscitation; DVT = deep venous thrombosis.

higher than 1.0 for age groups (indicated by confidence intervals that do not include 1.0) indicate a higher complication rate for the age group compared with the reference group (those 40–64 years of age). Because of the small number of cases, the mortality regression included only six age categories (with the top category 85+ years). The use of six or seven age categories allows us to determine the age at which the risk of experiencing each complication increased.

To answer our second question, another set of regressions was run including control variables for patient characteristics, comorbidities, and surgical conditions along with age. The control variables included age, race, sex, body mass index, a set of 17 patient comorbidities, whether the patient

Table 3. Thirty-day complication rates

Variable	Frequency	Percentage
NSQIP complications	530	5.92
NIH complications	349	3.90
Extended length of stay (days from operation to discharge > 7)	296	3.31
Return to the operating room	152	1.70
Urinary tract infection	140	1.56
Orthopaedic complications	136	1.52
DVT requiring treatment	131	1.46
Superficial incisional surgical site infection	84	0.94
Pulmonary embolism	68	0.76
Sepsis	45	0.50
Pneumonia	33	0.37
Unplanned reintubation	26	0.29
Wound disruption/dehiscence	21	0.23
Postoperative bleeding transfusion	17	0.19
Myocardial infarction	16	0.18
Progressive renal insufficiency	15	0.17
Septic shock	15	0.17
Deep incisional surgical site infection	13	0.15
Failure to wean off ventilator	12	0.13
Organ/space surgical site infection	12	0.13
30-day mortality	11	0.12
Peripheral nerve injury	11	0.12
Stroke/CVA with neurologic deficit	9	0.10
Acute renal failure	8	0.09
Cardiac arrest requiring CPR	8	0.09
Coma of longer than 24 hours	1	0.02
Prosthesis failure	2	0.02

NSQIP = National Surgical Quality Improvement Program; NIH = National Institutes of Health; DVT = deep vein thrombosis; CVA = cerebrovascular accident; CPR = cardiopulmonary resuscitation.

had undergone another operation in the prior 30 days, was of dependent functional status as assessed by Activities of Daily Living, received general anesthesia, was undergoing an emergency operation, and the year of the operation (Table 1). Only patients with complete data were included in the multivariate analyses. Thus, the effect of age in these regressions is the effect when other factors are controlled. Because of the small number of cases, mortality was only included in the first set of regressions.

To address our third question, we used the results of the second set of regressions to calculate the predicted probability that a patient with specified characteristics would experience a complication at different ages. The reference patient was defined as having the characteristics most common in the study population. Therefore, the reference patient was a white woman with a body mass index of 30 to 34 kg/m², who had a diagnosis of hypertension, received

general anesthesia, did not have diabetes, dyspnea, a bleeding disorder, a history of chronic obstructive pulmonary disease, congestive heart failure, angina, stroke, or peripheral vascular disease, and did not have a previous percutaneous coronary intervention or major previous cardiac surgery. The reference patient was not on steroid medications for a chronic condition, was of independent functional status, was not paraplegic, had not smoked within 1 year of surgery or had greater than two alcoholic drinks/day within 2 weeks of surgery, had not had a prior operation within 30 days, was not undergoing a revision or emergency operation, did not have an open wound/wound infection or sepsis, and was operated on in 2009. The age-specific risks were calculated for NSQIP complications and NIH complications because these are the outcomes in which age was a significant factor and there were adequate numbers of observations to perform the analysis. We performed all statistical analyses using Stata[®] SE Version 11.2 software (StataCorp, College Station, TX, USA) [25].

Results

Age was associated with increased risk of mortality starting at age 85 years; mortality for those 85 years and older was 17 times higher than for those younger than 65 years (Table 4). NSQIP complications increased starting at age 70 years, NIH complications at age 85 years, and extended length of stay at age 75 years (Table 4). Age was not associated with experiencing orthopaedic complications, DVT, or having to return to the operating room.

When comorbidities, sociodemographic factors, and surgical conditions were controlled, the effect of age was not changed much. When controlling for the other factors considered, age remained a predictor of higher risk of complications in older patients. NSQIP complications were approximately 1.5 times greater for those 70 to 74 years old relative to those 40 to 65 years old (Table 5), 3.1 times greater for those 85 to 89 years old, and approximately five times greater for those 90 years and older. Similarly, with comorbidities controlled, those 75 to 79 years of age were 1.5 times and those 85 years and older were two to three times more likely to experience NIH complications. With comorbidities controlled, those 85 to 89 years of age were 2.6 more likely to experience orthopaedic complications and patients 80 years and older were 2.2 to 3.5 times more likely to have an extended length of stay compared with those younger than 65 years. A body mass index of 40 kg/m² or greater was also associated with more NSQIP and NIH complications, and a body mass index of 35 kg/m² or greater was associated with more orthopaedic complications. Patient comorbidities were more often associated with extended length of stay than with any of the other

Table 4. Effect of age category on complications (odds ratios from logistic regression)

Variable	Mortality*		NSQIP complications		NIH complications		Orthopaedic complications		DVT		Return to operating room		Extended length of stay	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age (years)														
40–64	Reference		Reference		Reference		Reference		Reference		Reference		Reference	
65–69	2.28	0.32–16.22	1.14	0.88–1.49	0.95	0.69–1.32	1.03	0.64–1.68	0.96	0.57–1.60	0.82	0.51–1.32	1.19	0.82–1.71
70–74	1.21	0.11–13.33	1.36 [†]	1.05–1.76	1.19	0.87–1.62	0.96	0.57–1.59	1.01	0.61–1.69	0.75	0.45–1.25	1.14	0.78–1.66
75–79	2.85	0.40–20.25	1.46 [†]	1.20–1.91	1.20	0.86–1.66	0.97	0.56–1.66	1.02	0.60–1.76	1.11	0.70–1.78	1.94 [†]	1.38–2.72
80–84	2.57	0.23–28.41	1.46 [†]	1.05–2.03	1.27	0.85–1.89	1.07	0.55–2.05	1.24	0.66–2.33	0.88	0.46–1.68	2.58 [†]	1.77–3.76
85–89	17.65 [†]	2.94–106.04	2.71 [†]	1.81–4.06	2.05 [†]	1.23–3.42	1.87	0.84–4.15	1.98	0.89–4.42	1.54	0.70–3.40	2.85 [†]	1.67–4.87
≥ 90	–		4.25 [†]	2.04–8.87	2.98 [†]	1.14–7.61	2.73	0.65–11.53	2.90	0.69–12.26	2.26	0.54–9.48	5.39 [†]	2.24–12.96
Pseudo r ²	0.0558		0.0087		0.0042		0.0026		0.0032		0.0033		0.0173	

* For mortality, the highest age category is 85+ years; [†]significant result: $p < 0.05$; NSQIP = National Surgical Quality Improvement Program; NIH = National Institutes of Health; DVT = deep vein thrombosis; OR = odds ratio; 95% CI = 95% confidence interval.

Table 5. Effects of age, patient characteristics, and surgical characteristics on six complications (odds ratios from logistic regressions)

Variable	NSQP complications		NIH complications		Orthopaedic complications		DVT		Return to operating room		Extended length of stay	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age (years)												
40–64	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
65–69	1.15	0.87–1.52	0.96	0.68–1.36	1.02	0.61–1.71	0.88	0.49–1.55	0.70	0.42–1.18	1.06	0.72–1.56
70–74	1.49*	1.13–1.97	1.28	0.92–1.79	1.15	0.67–1.96	0.93	0.52–1.67	0.66	0.38–1.14	0.89	0.59–1.35
75–79	1.67*	1.25–2.25	1.45*	1.01–2.08	1.33	0.74–2.36	1.20	0.66–2.19	1.08	0.64–1.82	1.51*	1.03–2.22
80–84	1.70*	1.18–2.45	1.51	0.97–2.36	1.46	0.71–3.03	1.47	0.72–3.02	0.91	0.46–1.82	2.15*	1.41–3.27
85–89	3.10*	1.97–4.89	2.43*	1.37–4.31	2.55*	1.02–6.33	1.94	0.72–5.20	1.22	0.47–3.19	2.24*	1.25–4.01
≥ 90	4.97*	2.19–11.25	3.11*	1.04–9.32	1.79	0.22–14.81	3.92	0.79–19.44	2.00	0.43–9.37	3.51*	1.31–9.42
Race												
Non-Hispanic white	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Non-Hispanic black	1.33	0.96–1.85	1.09	0.72–1.66	0.73	0.35–1.53	1.65	0.90–3.03	1.11	0.58–2.10	1.81*	1.20–2.72
Hispanic	1.00	0.73–1.37	1.05	0.72–1.53	0.90	0.49–1.66	1.10	0.59–2.05	1.05	0.59–1.86	1.05	0.70–1.58
Asian-Pacific Islander-Native Hawaiian	1.05	0.51–2.18	1.48	0.68–3.23	1.13	0.27–4.70	Reference	Ref	4.95*	2.40–10.24	1.45	0.66–3.19
American Indian or Alaska Native	1.56	0.55–4.40	1.16	0.28–4.84	1.33	0.18–9.85	Reference	Ref	2.74	0.65–11.59	0.76	0.10–5.67
Sex												
Male	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Female	0.95	0.78–1.16	0.87	0.68–1.10	0.89	0.62–1.30	0.97	0.64–1.45	0.72	0.51–1.03	0.96	0.74–1.26
Body mass index (kg/m²)												
< 18.5	1.44	0.42–4.93	1.50	0.34–6.61	Reference	Reference	4.17	0.84–20.71	Reference	Reference	Reference	Reference
18.5–24.9	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Ref	Reference	Reference	Reference	Reference
25–29.9	0.94	0.66–1.32	0.95	0.62–1.45	1.18	0.53–2.64	1.04	0.50–2.18	1.65	0.79–3.43	0.77	0.52–1.15
30–34.9	1.09	0.77–1.54	1.15	0.75–1.76	1.86	0.85–4.07	1.31	0.63–2.75	1.97	0.94–4.13	0.76	0.51–1.15
35–39.9	1.30	0.89–1.88	1.51	0.96–2.38	2.56*	1.14–5.75	1.73	0.79–3.76	1.64	0.74–3.65	0.58*	0.36–0.93
≥ 40	1.78*	1.20–2.62	1.83*	1.13–2.96	3.25*	1.40–7.51	1.62	0.70–3.77	2.00	0.87–4.60	0.72	0.43–1.18
Comorbidities												
Diabetes	0.93	0.73–1.18	0.86	0.64–1.16	1.07	0.69–1.65	0.93	0.56–1.52	1.10	0.73–1.68	1.21	0.90–1.64
Current smoker within 1 year	1.15	0.82–1.60	1.35	0.92–1.87	1.53	0.88–2.68	0.73	0.35–1.54	1.28	0.75–2.20	0.70	0.42–1.17
Current alcohol use	1.01	0.52–1.94	1.12	0.54–2.33	1.52	0.54–4.26	1.89	0.67–5.33	1.51	0.60–3.81	0.18	0.02–1.28
Dyspnea	1.11	0.83–1.45	1.05	0.74–1.50	1.12	0.67–1.88	0.81	0.42–1.54	1.35	0.81–2.24	1.43*	1.01–2.03
History of severe COPD	1.05	0.67–1.63	0.83	0.46–1.51	0.85	0.35–2.03	0.65	0.20–2.15	0.86	0.36–2.05	1.60	0.96–2.65
CHF within 30 days of surgery	1.12	0.24–5.33	1.78	0.37–8.58	2.15	0.25–18.42	2.68	0.26–27.28	–	–	6.13*	1.86–20.22
Previous PCI	1.20	0.86–1.69	1.09	0.71–1.66	0.89	0.43–1.82	1.43	0.72–2.81	1.42	0.80–2.55	1.06	0.69–1.64
Previous cardiac surgery	1.18	0.79–1.75	1.50	0.96–2.34	1.03	0.56–2.30	0.99	0.42–2.37	1.07	0.52–2.20	1.54	0.99–2.41
History of angina within 1 month	1.05	0.40–2.73	1.36	0.47–3.94	0.78	0.10–6.20	3.02	0.84–10.83	–	–	0.95	0.30–3.06

Table 5. continued

Variable	NSQIP complications		NIH complications		Orthopaedic complications		DVT		Return to operating room		Extended length of stay	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Hypertension	1.14	0.91–1.42	1.10	0.84–1.43	1.15	0.75,1.75	0.96	0.62–1.48	1.19	0.79–1.78	1.52*	1.10–2.08
History of PVD	1.56	0.69–3.53	1.82	0.71–4.67	1.84	0.43–7.85	3.95*	1.17–3.32	2.33	0.70–7.79	0.23	0.02–1.72
Paraplegia	2.09	0.80–5.47	2.67	0.92–7.70	3.61	0.83–15.64	3.68	0.84–16.08	2.77	0.64–11.97	0.55	0.07–4.10
Open wound infection	1.96	0.73–5.26	2.39	0.80–7.11	4.74*	1.36–16.44	1.25	0.13–12.39	2.32	0.52–10.46	1.88	0.58–6.14
Steroid use for chronic condition	2.06*	1.32–3.20	1.68	0.94–3.01	1.86	0.79–4.36	1.56	0.56–4.34	0.79	0.25–2.54	1.36	0.72–2.59
Bleeding disorder	1.52	0.98–2.36	1.38	0.79–2.39	1.19	0.47–3.01	1.03	0.37–2.89	1.32	0.56–3.10	2.23*	1.39–3.60
Preoperative sepsis	0.67	0.09–5.00	1.07	0.14–8.02	–	–	3.16	0.41–24.24	–	–	2.63	0.59–11.68
Prior operation within 30 days	0.77	0.10–5.78	1.28	0.17–9.71	–	–	4.14	0.53–32.12	–	–	–	–
Stroke	0.95	0.65–1.39	0.77	0.46–1.28	0.99	0.47–2.08	0.56	0.20–1.56	0.66	0.29–1.54	1.62*	1.09–2.40
Dependent status	1.08	0.69–1.70	0.87	0.48–1.60	1.08	0.46–2.54	0.78	0.27–2.24	1.91	0.97–3.76	1.95*	1.21–3.13
Year of operation												
2005–2007	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
2008	0.98	0.73–1.31	1.25	0.85–1.83	0.63	0.37–1.09	1.55	0.82–2.95	0.72	0.44–1.20	0.68*	0.48–0.96
2009	0.83	0.63–1.10	1.06	0.74–1.53	0.81	0.50–1.31	0.93	0.50–1.76	0.71	0.44–1.12	0.49*	0.35–0.68
Nongeneral anesthesia	0.79*	0.66–0.96	0.85	0.68–1.07	0.88	0.62–1.27	0.94	0.65–1.37	1.05	0.75–1.49	0.49*	0.37–0.63
Emergency case	0.57	0.08–4.21	0.89	0.12–6.62	–	–	2.41	0.32–18.33	–	–	0.89	0.12–6.68
No.	8410		8410		8450		8410		8450		8450	
Pseudo r^2	0.0244		0.0185		0.0278		0.0312		0.0326		0.0774	
ROC	0.6225		0.6096		0.6362		0.6332		0.6601		0.7250	

* Significant result: $p < 0.05$; – = not in equation; NSQIP = National Surgical Quality Improvement Program; NIH = National Institutes of Health; DVT = deep vein thrombosis; OR = odds ratio; 95% CI = 95% confidence interval; COPD = chronic obstructive pulmonary disease; CHF = congestive heart failure; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease; ROC = receiver operating characteristic.

Fig. 1 The graph shows predicted age-specific risk of experiencing NSQIP complications and NIH complications for a reference patient. The reference patient is a white woman, who has a body mass index (BMI) of 30 to 34 kg/m², has a diagnosis of hypertension, received general anesthesia, does not have diabetes, dyspnea, a bleeding disorder, a history of chronic obstructive pulmonary disease, congestive heart failure, angina, stroke, or peripheral vascular disease, has not had a previous percutaneous coronary intervention or major previous cardiac surgery, is not on steroid medications for a chronic condition, is of independent functional status, is not paraplegic, has not smoked within 1 year of surgery or had greater than two drinks/day within 2 weeks of surgery, has not had a prior operation within 30 days or is not undergoing a revision or emergency operation, does not have an open wound/wound infection or sepsis, and was operated on in 2009.

complications. General anesthesia was associated with an increased risk of NSQIP morbidities and with extended length of stay.

The probability of experiencing a NSQIP complication for the reference patient increased from 4.0% at ages 40 to 64 years to 17.2% in patients 90 years and older (Fig. 1). The risk of NIH complications increased from 2.8% for those aged 40 to 64 years to 8.3% for those aged 90 years or older. The probability of both NSQIP and NIH complications increases markedly after age 80 years.

Discussion

The aging of the population, along with the increasing use of knee arthroplasty among aged patients, has increased the importance of a clearer understanding of age-associated risk for this largely elective surgery. Our aim was to quantify the age at which rates of different types of short-term complications increase; to determine whether the increase in complications with age could be explained by age-related patient comorbidities, other sociodemographic characteristics, and surgical conditions; and to estimate the probability of complications of various types at different ages for an average patient. Most prior studies have relied

on relatively small samples of arthroplasties, which have not allowed investigation of either age variability within the older population or of rare complications [3, 8, 9, 11, 23]. Even some studies with relatively large samples have included all patients age 65 years and older in one group [24]; and most studies have not been able to assess mortality risk [22]. We therefore addressed three questions surrounding short-term (eg, 30-day) postoperative morbidity and mortality: (1) At what ages do different types of complications increase? (2) Is the increase in complications with age the result of age-related patient comorbidities, sociodemographic characteristics, and surgical conditions? (3) What is the probability of complications at different ages for an average patient? Answers to these questions will help surgeons and patients to understand the risks associated with knee arthroplasty at a given age and the risks with age that are not predicted by comorbidities to guide decision-making.

Although the NSQIP database is one of the best available for studying surgical complications, there are a number of limitations to be considered. First, the program demands of NSQIP may limit the participation of community hospitals in the program. It is possible that differences by age in type of hospital used would result in patients not being equally represented by age in our sample. Complication rates may be higher (or lower) in nonparticipating hospitals, leading us to underestimate (or overestimate) complication rates, thereby reducing the generalizability of our study findings. Nonetheless, these prospectively collected data are generally high quality with a large patient sample, spanning the age range, collected from hospitals across the country presumably using appropriate surgical conditions and pre- and postoperative care. The inclusion of large numbers of patients at older ages was necessary for the power to perform these analyses. Second, although our data set included many patient characteristics, it does not include provider characteristics such as surgeon experience and hospital volume [23, 24], which would help to further understand the risk of complications with arthroplasty. If hospitals and surgeons with different characteristics vary in their likelihood of, or abilities in, treating older patients, this could affect our assessment of the independent role of age. Third, the data set is limited to complications that occur within 30 days of discharge so we are unable to add information on mid- or longer-term outcome measures reflecting function or health-related quality of life years after surgery. It is possible that the improvements in functioning and quality of life are relatively greater for the elderly meaning that the higher risk of complications may be justified and would need to be considered in counseling patients. However, the immediate complications are the ones that can be most effectively addressed by surgeons and institutions during the hospital stay.

We found mortality increases after age 85 years. Previous studies [4, 17, 22] did not have sufficient numbers of cases to examine mortality at precise older ages. Biau et al. found no relationship of age to mortality [4]. Parvizi et al. [17] described a relationship but could not specify the age at which it increased. We also found that NIH complications increased beginning at age 85 years and extended length of stay at 75 years; however, we found that when we considered all NSQIP complications, the increase began at age 70 years. The relative increase with age in all NSQIP complications we found is roughly similar to the 40% increase with each 10 years of age reported by Higuera et al. [8] based on a more limited study of 502 patients in Midwest regional hospitals. The difference between all NSQIP complications and those defined by the NIH group as specific for TKA includes a set of pulmonary, renal, neurologic, cardiac, and sepsis-related complications. The earlier age-related increases in all complications indicate a need to consider this wider set of complications when assessing risks at older ages.

The elevated risk associated with age remained after controls for patient comorbidities, additional sociodemographic factors, and characteristics of surgery. An important contribution of our study is that a patient who may not appear to be at increased risk of surgical complications based on comorbidities may indeed be at increased risk based on age alone. Our analysis also includes findings that extend the literature on links between complications of knee arthroplasty and comorbidities and surgical conditions. Other studies [3, 17] have reported higher body mass index associated with more surgical complications but we found the association limited to very obese (body mass index > 35 kg/m²) patients. We noted no sex difference in complications, in contrast to other reports in the literature [18], and by Kurtz et al. [12] who found women had lower risk of joint infection. Much of the literature reports that congestive heart failure and chronic obstructive pulmonary disease are associated with arthroplasty complications [5, 8, 9]. We, however, find congestive heart failure associated only with extended length of stay and chronic obstructive pulmonary disease unrelated to complications. Like Pugely et al. [21], who studied primary TKA, we found the use of nongeneral anesthesia was associated with fewer complications after primary total and partial knee arthroplasty.

We showed a sharp increase in complication rates after age 80 years so that they more than double for the group 90 years of age and older. In contrast to other studies [8, 21], we did not limit our assessment of age-related risk to relative risks; rather, we used our regression analysis to estimate the absolute probability of NSQIP and NIH complications by age for a reference patient to clarify the implications of the age effect. In determining the probability of complications, we estimated rates for an “average” patient, or one with the

most common characteristics. It is possible to do this for patients with widely varying characteristics and, in the future, it would be possible to develop an easily available computerized application that could produce the probability by age for individual patients using their own age, sociodemographic characteristics, comorbidities, and proposed surgical characteristics, which could be used in clinical settings.

In conclusion, we found the risk of experiencing any complication from knee arthroplasty begins to increase at age 70 years and increases markedly after age 80 years. On the other hand, mortality does not substantially increase until age 85 years. Although prior studies have indicated that older age was linked to higher risk of complications, our findings suggest variability in age-associated risk for various types of complications [8, 9, 21]. Surgeons may use this information to counsel patients by providing age-specific risks as well as to anticipate possible early postoperative complications. Patients considering this elective operation should realize complications increase with older age and should take this into consideration in their decision-making process.

References

1. American College of Surgeons. ACS National Surgical Quality Improvement Program, program overview. Revised September 18, 2009. Available at: www.facs.org/cqi/outcomes.html. Accessed July 15, 2011.
2. American College of Surgeons. ACS NSQIP user guide for the 2009 participant use data file. October 2010. Available at: <http://site.acsnsqip.org/participant-use-data-file/>. Accessed June 2011.
3. Berend ME, Thong AE, Faris GW, Newbern G, Pierson JL, Ritter MA. Total joint arthroplasty in the extremely elderly: hip and knee arthroplasty after entering the 89th year of life. *J Arthroplasty*. 2003;18:817–821.
4. Biau D, Mullins MM, Judet T, Piriou P. Is anyone too old for a total knee replacement? *Clin Orthop Relat Res*. 2006;448:180–184.
5. Bozic KJ, Lau E, Kurtz S, Ong K, Berry DJ. Patient-related risk factors for postoperative mortality and periprosthetic joint infection in Medicare patients undergoing TKA. *Clin Orthop Relat Res*. 2012;470:130–137.
6. Gomez CR, Boehmer ED, Kovacs EJ. The aging innate immune system. *Curr Opin Immunol*. 2005;17:457–462.
7. Hall BL, Hamilton BH, Richards K, Bilimoria KY, Cohen ME, Ko CY. Does surgical quality improve in the American College of Surgeons National Surgical Quality Improvement Program: an evaluation of all participating hospitals. *Ann Surg*. 2009;250:363–376.
8. Higuera CA, Elsharkawy K, Klika AK, Brocone 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;469:1391–1400.
9. Huddleston JI, Maloney WJ, Wang Y, Verzier N, Hunt DR, Herndon JH. Adverse events after total knee arthroplasty: a national Medicare study. *J Arthroplasty*. 2009;24(Suppl):95–100.
10. Ingraham AM, Richards KE, Hall BL, Ko CY. Quality improvement in surgery: the American College of Surgeons

- National Surgical Quality Improvement Program approach. *Adv Surg.* 2010;44:251–267.
11. Joshi AB, Markovic L, Gill G. Knee arthroplasty in octogenarians: results at 10 years. *J Arthroplasty.* 2003;18:295–298.
 12. 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;468:52–56.
 13. Linton PJ, Dorshkind K. Age-related changes in lymphocyte development and function. *Nat Immunol.* 2004;5:133–139.
 14. Miller RA. The aging immune system: primer and prospectus. *Science.* 1996;273:70–74.
 15. NIH Consensus Statement on Total Knee Replacement. *NIH Consens State Sci Statements.* 2003;20:1–32.
 16. Núñez M, Lozano L, Núñez E, Segur JM, Sastre S, Maculé F, Ortega R, Suso S. Total knee replacement and health-related quality of life: factors influencing long-term outcomes. *Arthritis Rheum.* 2009;61:1062–1069.
 17. 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;89:27–32.
 18. Peterson CY, Osen HB, Tran Cao HS, Yu PT, Chang DC. The battle of the sexes: women win out in gastrointestinal surgery. *J Surg Res.* 2011;170:e23–e28.
 19. Plackett TP, Boehmer ED, Faunce DE, Kovacs EJ. Aging and innate immune cells. *J Leukoc Biol.* 2004;76:291–299.
 20. Plowden J, Renshaw-Hoelscher M, Engleman C, Katz J, Sambhara S. Innate immunity in aging: impact on macrophage function. *Aging Cell.* 2004;3:161–167.
 21. 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;95:193–199.
 22. Santaguida PL, Hawker GA, Hudak PL, Glazier R, Mahomed NN, Kreder HJ, Coyte PC, Wright JG. Patient characteristics affecting the prognosis of total hip and knee joint arthroplasty: a systematic review. *Can J Surg.* 2008; 51:428–436.
 23. Solomon DH, Chibnik LB, Losina E, Huang J, Fossel AH, Husni E, Katz JN. Development of a preliminary index that predicts adverse events after total knee replacement. *Arthritis Rheum.* 2006;54:1536–1542.
 24. SooHoo NF, Lieberman JR, Ko CY, Zingmond DS. Factors predicting complication rates following total knee replacement. *J Bone Joint Surg Am.* 2006;88:480–485.
 25. StataCorp. *Stata Statistical Software: Release 11.* College Station, TX, USA: StataCorp LP; 2009.
 26. US Department of Health and Human Services. Administration on Aging. Aging statistics. Modified September 1, 2011. Available at: www.aoa.gov/aoaroot/aging_statistics/index.aspx. Accessed September 1, 2012.