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CLINICAL RESEARCH

Do Patients With Insulin-dependent and Noninsulin-dependent Diabetes Have Different Risks for Complications After Arthroplasty?

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Abstract

Background Patients with diabetes are known to be at greater risk for complications after arthroplasty than are patients without diabetes. However, we do not know whether there are important differences in the risk of perioperative complications between patients with diabetes who are insulin-dependent (Type 1 or 2) and those who are not insulin-dependent.

Questions/purposes The purpose of our study was to compare (1) medical complications (including death), (2) surgical complications, and (3) readmissions within 30 days between patients with insulin-dependent and noninsulin-dependent diabetes, and with patients who do not have diabetes.

Methods A total of 43,299 patients undergoing THA or TKA between 2005 and 2011 were selected from the American College of Surgeon's National Surgical Quality Improvement Program's (ACS-NSQIP®) database. Generalized linear models were used to assess the relationship between diabetes status and outcomes (no diabetes [n = 36,574], insulin dependent [n = 1552], and noninsulin dependent [n = 5173]). Multivariate models were established adjusting for confounders including age, sex, race, BMI, smoking, steroid use, hypertension, chronic obstructive pulmonary disease, and anesthesia type. Post hoc comparisons between patient groups were made using a Bonferroni correction.

Results Patients who were insulin dependent had increased odds of experiencing a medical complication (OR, 1.6; 95% CI, 1.2–2.0; $p < 0.001$), as did patients who were noninsulin dependent (OR, 1.2; 95% CI, 1.1–1.4; $p < 0.001$). An increased likelihood of 30-day mortality was found only for patients who were insulin dependent (OR, 3.74; 95% CI, 1.6–8.5; p = 0.007). However, neither diabetic state was associated with surgical complications. Finally, readmission was found to be independently associated with insulin-dependent diabetes (OR, 1.6; 95% CI, 1.1–2.1; p = 0.023).

Conclusions Patients with insulin-dependent diabetes are most likely to have a medical complication or be readmitted within 30 days after total joint replacement. However, patients who are insulin dependent or noninsulin dependent are no more likely than patients without diabetes to have a surgical complication. Physicians and hospitals should keep these issues in mind when counseling patients and generating risk-adjusted outcome reports.

Level of Evidence Level III, therapeutic study. See the Instructions for Authors for a complete description of levels of evidence.

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Introduction

The prevalence of diabetes mellitus is high in older patients, with 26.9% of US residents older than 65 years with the disease [3]. In addition, an estimated 79 million Americans 20 years or older currently are considered prediabetic [3]. Diabetes has been implicated as a risk factor for increased rates of surgical site infections, urinary tract infections, pneumonia, and stroke after lower extremity arthroplasty [2, 8–14, 17]. However, other studies challenge the role of diabetes as a risk factor, even for classic associations such as diabetes and wound infections [1, 4, 5].

Moreover, diabetes is a heterogeneous state and can be classified using many parameters. Data suggest that perioperative hemoglobin A1c and serum glucose levels may better predict infection after arthroplasty [8, 9, 12]. Diabetic state also may be classified using the method of diabetic control. For example, Iorio et al. [8] and Meding et al. [13] reported that patients with insulin-dependent diabetes had higher rates of infections after arthroplasty compared with patients with noninsulin-dependent diabetes. Thus, patients with insulin-dependent diabetes and patients with noninsulin-dependent diabetes may differ in terms of their surgical risk profiles, but this relationship remains poorly characterized.

We therefore used a large, multiinstitutional patient registry to determine whether distinct codeable, diabetic disease states (insulin-dependent diabetes [including Types 1 and 2] and noninsulin dependent diabetes) portend different risks for surgical and medical complications after TKA and THA. We also sought to determine whether these two groups have different risks for 30-day readmission when compared with patients without diabetes.

Patients and Methods

The design and statistical methods of the American College of Surgeon's National Surgical Quality Improvement Program (ACS-NSQIP®) was described by Henderson and Daley [7]. Briefly, the ACS-NSQIP® collects demographic information, intraoperative variables, and 30-day postoperative complications for patients who underwent major surgical procedures. These data are obtained from more than 250 sites and are retrieved directly from patients' medical records. Specifically, the merged Participant Use Data Files from 2005 to 2011 contain 135 variables from 1,777,035 deidentified cases. Of those, a total of 46,913 patients underwent either primary THA (CPT code, 27130) or TKA (CPT code, 27447); 43,299 had osteoarthritis (ICD-9 code 715). Other patients were excluded from this analysis.

As most of the demographic variables are categorical, they are presented as counts and percentages and compared across diabetic status groups using chi-square tests. BMI was normally distributed, and therefore was compared using ANOVA tests and presented as mean and SD. Total Work Relative Value Unit (RVU) was calculated based on the RVU of the primary procedure and any concurrent or other procedure listed. Age and total RVU were not normally distributed, so distributions were compared using Wilcoxon rank sum tests and are presented as median and 25th and 75th percentiles.

Diabetic status was among the variables collected and was grouped into three categories: insulin, noninsulin, and nondiabetic. The insulin category included any patients with diabetes currently using insulin (Types 1 and 2), whereas the noninsulin category included patients with diabetes using only noninsulin medications to control their disease. Age, sex, and race differed slightly between the insulin-dependent, noninsulin-dependent, and nondiabetic cohorts (Table 1). Mean BMI was highest among patients with insulin-dependent diabetes mellitus (35 $\pm$ 6 insulin dependent versus 34 $\pm$ 6 noninsulin dependent versus 31$\pm$ 6 nondiabetic; $p < 0.001$). The proportion of patients classified as American Society of Anesthesiologists' (ASA) Class 3 provides a succinct summary of how the comorbidity burden differed among the cohorts (77.5% with insulin-dependent diabetes mellitus versus 66.4% with noninsulin-dependent diabetes mellitus versus 40.0% nondiabetic; $p < 0.001$). The same trends were seen in the knee (Appendix 1. Supplemental material is available with the online version of CORR.) and hip (Appendix 2. Supplemental material is available with the online version of CORR.) subgroup analyses.

Our primary comparisons included rates of medical complications (including death), surgical complications, and readmission. Endpoints of interest were compared across diabetic status groups using generalized linear mixed models, using logit, or log links, depending on the distribution of the outcome (logistic regression for binary outcomes or negative binomial for total length of hospital stay). Unadjusted analyses are presented as multivariable analyses that were adjusted for potential confounders (ASA classification, age, sex, race, BMI, hypertension, steroid use, history of chronic obstructive pulmonary disease, preoperative laboratory values, anesthetic type, and total RVU). Odds ratios, least-squared estimated means, and hazard ratios are presented with corresponding Bonferroni adjustments for post hoc comparisons across diabetic status groups. Secondary analyses stratified all analyses by procedure (THA or TKA). All analyses were run at a type I error rate of 5%, and all analyses were run in SASv9.2 (Cary, NC, USA).

Table 1. Preoperative characteristics

Characteristic	Without diabetes	Noninsulin dependent	Insulin dependent	p value
Number of patients	36,574	5173	1552	–
Age (years) (median [25th,75th percentiles])	66 (59, 74)	68 (62, 75)†	67 (61, 74)‡	< 0.001
BMI	30.9 (6.2)	34.0 (6.2)†	35.2 (6.3)†,‡	< 0.001
Sex (male)	14,041 (38.6%)	2157 (41.9%)†	674 (43.5%)†	< 0.001
Race		†	†,‡	< 0.001
White	30,264 (83.7%)	4033 (78.8%)	1234 (80.6%)	
Black	2153 (6.0%)	444 (8.7%)	160 (10.5%)	
Asian	486 (1.3%)	141 (2.8%)	25 (1.6%)	
Hispanic	123 (0.3%)	23 (0.5%)	9 (0.6%)	
Other/unknown	3148 (8.7%)	475 (9.3%)	103 (6.7%)	
Active smoker	3653 (10.0%)	438 (8.5%)†	143 (9.2%)	0.002
Outpatient	294 (0.8%)	43 (0.8%)	18 (1.2%)	0.312
Steroid use	858 (2.4%)	104 (2.0%)	62 (4.0%)†,‡	< 0.001
Comorbidities				
Dyspnea	2606 (7.1%)	585 (11.3%)†	228 (14.7%)†,‡	< 0.001
Hypertension	22415 (61.3%)	4472 (86.5%)†	1389 (89.5%)†,‡	< 0.001
Chronic obstructive pulmonary disease	1233 (3.4%)	240 (4.6%)†	106 (6.8%)†,‡	< 0.001
Congestive heart failure < 30 days	55 (0.2%)	12 (0.2%)	10 (0.6%)†,‡	< 0.001
Bleeding disorders	884 (2.4%)	161 (3.1%)†	56 (3.6%)†	< 0.001
Previous percutaneous coronary Intervention	1347 (5.5%)	359 (10.0%)†	173 (16.5%)†,‡	< 0.001
Previous cardiac surgery	974 (4.0%)	246 (6.8%)†	126 (12.0%)†,‡	< 0.001
Previous stroke with neurologic deficit	236 (1.0%)	46 (1.3%)	33 (3.1%)†,‡	< 0.001
Previous stroke without neurologic deficit	402 (1.6%)	96 (2.7%)†	44 (4.2%)†,‡	< 0.001
ASA class		†	†,‡	< 0.001
1–2	21,453 (58.7%)	1602 (31.0%)	257 (16.6%)	
3	14,608 (40.0%)	3425 (66.4%)	1203 (77.5%)	
4–5	461 (1.3%)	135 (2.6%)	92 (5.9%)	
Total relative value units (median [25th,75th percentiles])	23.0 (21.8, 23.3)	23.3 (21.8, 23.3)†	23.3 (23.0, 23.3)†	< 0.001

† Post hoc test, significantly different from patients without diabetes; ‡post hoc test, significantly different from patients with noninsulin-dependent diabetes mellitus.

Results

Patients with diabetes were more likely to have medical complications after arthroplasty than patients without diabetes, and patients with insulin-dependent diabetes were at greater risk for medical complications than those with noninsulin-dependent diabetes. In the combined hip and knee analysis, the baseline rate for a medical complication changed with diabetic status (7.0% insulin dependent versus 5.0% noninsulin dependent versus 3.4% nondiabetic; $p < 0.001$) (Table 2). Insulin-dependent diabetes mellitus was associated with an increased likelihood of experiencing a medical complication when compared with noninsulin-dependent diabetes and no diabetes (OR, 1.6, 95% CI, 1.2–2.1). In addition, insulin-dependent diabetes mellitus was associated with increased 30-day mortality (OR, 3.7; 95% CI, 1.4–10.3). Regarding specific complications, patients with insulin-dependent diabetes mellitus had greater odds of experiencing a cerebrovascular accident or pneumonia when compared with patients without diabetes (OR, 4.2; 95% CI, 1.3–13.4; and OR, 2.3; 95% CI, 1.1–4.9, respectively). Finally, noninsulin-dependent diabetes mellitus conferred an increased likelihood of medical complications, but to a smaller degree than insulin-dependent diabetes mellitus (OR, 1.22; 95% CI, 1.01–1.48). Secondary subgroup analyses (Appendices 3 and 4. Supplemental material is available with the online version of CORR.) revealed that insulin dependence was strongly associated with medical complications and mortality especially after THA (OR, 1.9; 95% CI, 1.2–3.2; and OR, 12.2; 95% CI, 3.1–47.1, respectively).

In contrast, neither patients with insulin-dependent nor noninsulin-dependent diabetes mellitus had greater odds of a surgical complication (insulin dependent: OR, 1.3, 95% CI, 0.8–2.1; noninsulin-dependent: OR, 1.2, 95% CI, 0.98–1.4) compared with patients without diabetes. However,

Table 2. Outcomes after lower extremity arthroplasty

Outcomes	Unadjusted rates and odds ratios				Adjusted odds ratios*			
	Without diabetes	Noninsulin-dependent diabetes mellitus	Insulin-dependent diabetes mellitus	p value	Without diabetes	Noninsulin-dependent diabetes mellitus	Insulin-dependent diabetes mellitus	p value
Overall complication rate	4.5%	6.3%† 1.43 (1.23, 1.67)	8.8%†,‡ 2.05 (1.64, 2.57)	< 0.001	–	1.16 (0.98, 1.38)	1.48 (1.15, 1.90)†	< 0.001
Surgical complications	1.2%	1.5% 1.28 (0.95, 1.72)	2.3%† 1.92 (1.26, 2.94)	< 0.001	–	0.93 (0.67, 1.31)	1.27 (0.78, 2.07)	0.395
Superficial wound	0.7%	1.0% 1.43 (1.00, 2.05)	1.3%† 1.77 (1.01, 3.09)	0.005	–	1.16 (0.77, 1.73)	1.21 (0.63, 2.31)	0.588
Deep incision/organ space	0.3%	0.4% 1.29 (0.73, 2.28)	0.6% 2.06 (0.93, 4.54)	0.065	–	0.86 (0.44, 1.68)	1.40 (0.59, 3.36)	0.507
Medical complications**	3.4%	5.0%† 1.47 (1.24, 1.74)	7.0%†,‡ 2.13 (1.66, 2.72)	< 0.001	–	1.22 (1.01, 1.48)†	1.56 (1.18, 2.06) †	< 0.001
Pneumonia	0.3	0.4 1.29 (0.71, 2.35)	0.9†,‡ 3.19 (1.61, 6.33)	< 0.001	–	0.81 (0.40, 1.65)	2.32 (1.11, 4.85) †,‡	0.011
Unplanned intubation	0.2%	0.3%† 2.01 (1.04, 3.88)	0.7%† 4.34 (1.98, 9.55)	< 0.001	–	1.50 (0.72, 3.11)	2.63 (1.08, 6.42) †	0.027
On ventilation > 48 hours	0.1%	0.1% 1.36 (0.42, 4.38)	0.3%† 4.54 (1.41, 14.65)	0.003	–	0.98 (0.29, 3.32)	2.01 (0.51, 8.01)	0.456
Renal insufficiency	0.1%	0.3%† 3.20 (1.48, 6.92)	0.6%† 7.65 (3.19, 18.30)	< 0.001	–	1.67 (0.71, 3.94)	3.33 (1.29, 8.60) †	0.009
Urinary tract infection	1.2%	1.9%† 1.56 (1.19, 2.04)	2.4%† 2.07 (1.37, 3.11)	< 0.001	–	1.33 (0.99, 1.80)	1.53 (0.97, 2.42)	0.014
Stroke/cerebrovascular accident	0.1%	0.1% 1.18 (0.44, 3.13)	0.5%† 3.94 (1.48, 10.49)	0.004	–	0.97 (0.30, 3.15)	4.23 (1.34, 13.37) †,‡	0.009
Cardiac arrest	0.1%	0.2% 2.36 (0.94, 5.93)	0.3% 3.50 (0.97, 12.63)	0.012	–	1.68 (0.53, 5.38)	2.38 (0.50,11.40)	0.309
Myocardial infarction	0.2%	0.5%† 3.11 (1.80, 5.35)	0.8%† 4.45 (2.09, 9.46)	< 0.001	–	3.07 (1.69, 5.57)	3.76 (1.60, 8.84)	< 0.001
Sepsis or sepsis shock	0.4%	0.8%† 2.09 (1.37, 3.18)	1.4%† 3.49 (1.99, 6.14)	< 0.001	–	1.61 (1.02, 2.56) †	1.94 (1.02, 3.69) †	0.007
Return to operating room	1.4%	1.7% 1.17 (0.88, 1.54)	2.1% 1.44 (0.92, 2.23)	0.075	–	0.85 (0.62, 1.18)	0.97 (0.58, 1.60)	0.501
Total length of stay (mean days, 95% CI)	3.4 (3.4, 3.5)	3.7 (3.6, 3.7)†	4.0 (3.9, 4.1) †,‡	< 0.001	4.3 (4.1, 4.4)	4.4 (4.2, 4.5)	4.6 (4.4, 4.8) †,‡	< 0.001
Time from operating room to discharge (hazard ratio)	–	0.89 (0.87, 0.92)†	0.81 (0.77, 0.86) †,‡	< 0.001	–	0.97 (0.94, 1.00)	0.91 (0.86, 0.96) †	0.001
Readmission	3.9%	4.9% 1.28 (0.99, 1.66)	8.0%†,‡ 2.15 (1.51, 3.06)	< 0.001	–	1.01 (0.75, 1.34)	1.56 (1.06, 2.30) †	0.023
30-day mortality rate	0.1%	0.3% 1.92 (0.91, 4.06)	0.6%† 4.94 (2.14, 11.37)	< 0.001	–	1.50 (0.62, 3.63)	3.74 (1.37,10.25) †	0.007

*Adjusted for American Society of Anesthesiologists class, smoking status, steroid use, hypertension medications, history of chronic obstructive pulmonary disease, creatinine, platelet counts, white blood cell counts, anesthesia type (general or not), race, age, sex, BMI, and total relative value units; **specific medical complication rates with differences between diabetes study groups < 0.01; †post hoc test significantly different from that of patients without diabetes; ‡post hoc test significantly different from that of patients with noninsulin-dependent diabetes.

secondary subgroup analyses (Appendices 3 and 4. Supplemental material is available with the online version of CORR.) showed that patients with insulin-dependent diabetes had an increased risk of deep infection after TKA compared with the cohorts with noninsulin-dependent diabetes and without diabetes (OR, 3.1; 95% CI, 1.1–8.5). Additionally, patients with insulin-dependent diabetes showed an increased odds of superficial wound infection after THA (OR, 3.4; 95% CI, 4.0–8.1) compared with patients without diabetes.

Patients with insulin-dependent diabetes were more likely to be readmitted within 30 days, while patients with noninsulin-dependent diabetes had the same likelihood of readmission as patients without diabetes (Table 2). In the combined analysis, baseline readmission rates were greatest for patients with insulin-dependent diabetes mellitus (8.0%; $p < 0.001$). Insulin-dependent diabetes mellitus showed an independent association with readmission in the combined group (OR, 1.6; 95% CI, 1.1–2.3). However, noninsulin-dependent diabetes was not associated with readmission (OR, 1.0; 95% CI, 0.8–1.3). In the TKA subgroup analysis, readmission was not associated with either form of diabetes (insulin-dependent diabetes mellitus: OR, 1.37; 95% CI, 0.84–2.22; noninsulin-dependent diabetes mellitus: OR, 0.98; 95% CI, 0.69–1.39).

Discussion

Clinicians generally believe that diabetes increases the risk of perioperative complications in patients having total joint arthroplasties, but the exact risk is not well defined [1, 2, 4, 5, 8–14, 17]. The effect of diabetic disease state on risk of complication after THA and TKA is less well understood [8, 13]. We therefore sought to use a large, multiinstitutional patient registry to determine whether patients with insulin-dependent diabetes and noninsulin-dependent diabetes have different likelihoods for medical and surgical complications after TKA and THA (including death). We also investigated whether patients with diabetes are more likely to experience 30-day readmissions.

There were limitations to our study. Although the ASC-NSQIP® is a clinical database, it does not necessarily capture details of each patient's clinical course. Furthermore, some variables are more subject to coding problems than others, a consideration that must be made in judging the accuracy of our conclusions. For example, superficial wound infections are difficult to diagnose clinically, while death or readmission is an easy variable to define and track. The second limitation of our study is that certain variables were not available to us through the ACS-NSQIP®. For example, perioperative serum hemoglobin A1c and glucose levels, which reflect varying levels of diabetic control, are not available in the ASC-NSQIP® database. Furthermore, the duration of disease, presence of peripheral neuropathy, previous foot and/or leg infection, or other late manifestations of diabetes are unavailable in the database. However, we believe the practical applications of our findings are worthwhile, especially in the development of risk assessment tools for patients undergoing surgery. Third, we were unable to control for factors such as hospital type, surgeon volume, or insurance status, owing to the deidentified nature of the registry. Although these factors may influence patient outcomes, we believe that the variety of participating hospitals in the ACS-NSQIP® leads to generalizable findings. Fourth, the cohorts were shown to have significant differences in BMI, severe chronic obstructive pulmonary disease, congestive heart failure, steroid use, and hypertension—factors that may influence rate of complications and wound healing [5, 14]. We also noted differences in age, sex, and race between our groups. Although we used logistic regression to control for these factors, statistical techniques may be limited in their ability to dissect the complex interplay of patient comorbidities in their effect on changing complication risk. Fifth, the ACS-NSQIP® database has a 30-day followup period, which affects some findings more than others. We believe that the trends seen in wound complication rates in patients with insulin-dependent diabetes mellitus are good approximations of the increase in postoperative risk of infection. However, reoperations most likely would be greater if followup were longer. Finally, second-order comparisons made in studies with a large number of simultaneous comparisons must be considered preliminary. Although we attempted to control for multiple comparisons using Bonferroni corrections, differences in specific surgical complications (for example, surgical site infections) and medical complications (for example, pneumonia) will require confirmation by future studies.

We found that classifying patients with diabetes by insulin dependence results in two separate risk profiles, with patients with insulin-dependent diabetes at the greatest risk for medical complications. The association with complications is more pronounced after THA, suggesting that diabetic disease state matters even more in these patients. Previous studies [9, 12] used controlled versus uncontrolled diabetes as a measure of diabetic disease state when assessing risk of medical complications after lower extremity arthroplasty. Marchant et al. [12] found that uncontrolled diabetes was associated with more stroke, urinary tract infections, and death when compared with controlled diabetes. Given that hemoglobin A1c levels of 7.0 are not always feasible for patients with diabetes undergoing total joint arthroplasty [6], we hope that this novel way of looking at diabetic disease state may provide a complementary mode of risk stratification before joint replacement.

Previous studies have classified patients with diabetes by insulin status when assessing their risk of surgical infection. In one series, Meding et al. [13] reported a higher rate of deep infections after knee arthroplasty in patients who were insulin dependent compared with patients who were noninsulin dependent. Iorio et al. [8] reported an infection rate of 11.1% in the cohort that was insulin dependent and 1.4% in the cohort that was noninsulin dependent who were undergoing lower extremity arthroplasty. We found that neither noninsulin-dependent nor insulin-dependent diabetes mellitus was independently associated with overall surgical complication risk. However, examining specific complications in the subgroups provided preliminary evidence that patients with insulin-dependent diabetes mellitus were more likely to experience a superficial infection after THA or a deep infection after TKA. If the followup time were greater in our study, our rates of observed infection might more closely approximate those reported by Iorio et al. [8].

Insulin-dependent diabetes was associated with a higher risk of readmission during the study period. The most common reasons for readmission after arthroplasty relate to complications after surgery [15, 16, 18], so higher complication rates in patients who are insulin dependent would logically explain our results. Although a secondary finding, we noted that neither noninsulin-dependent nor insulin-dependent diabetes was associated with increased rates of reoperation. However, increasing followup time might influence this observation.

The prevalence of diabetes in the population undergoing arthroplasty is high and may increase in the future. We showed that adverse outcomes are greatest for patients with diabetes whose disease is either severe or chronic enough to merit insulin use. We believe that our findings support the simple and pragmatic use of a diabetic glucose control method as a variable for risk in the preoperative assessment of patients with diabetes who are undergoing arthroplasty. Our findings help clinicians better define perioperative risk when counseling patients, and provide a rationale for using simple codeable data when generating risk adjustment schemes for public reporting and reimbursement.

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