Research Article

Diabetes Status Affects Odds of Body Mass Index–dependent Adverse Outcomes After Total Hip Arthroplasty

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Abstract

Introduction: Obesity and diabetes have independently been shown to predispose to adverse outcomes after total hip arthroplasty (THA). These may have a coupled effect on perioperative risks. The purpose of this study was to evaluate the effect of body mass index (BMI) on adverse outcomes in nondiabetic (ND), non–insulin-dependent diabetes mellitus (NIDDM), and insulin-dependent diabetes mellitus (IDDM) patients.
Methods: Patients undergoing primary THA were selected from the National Surgical Quality Improvement Program Database from 2012 to 2016 and categorized as ND, NIDDM, and IDDM. BMI, demographics, and 30-day perioperative outcomes were assessed for each group. Multivariate logistic regressions controlling for demographics, functional status, and American Society of Anesthesiologists were used to determine the odds ratio of serious adverse event (SAE) in each diabetes group for patients with BMI ≥ 40 kg/m^2 compared with a control group of ND patients with a normal BMI (18.5 to 24.9 kg/m^2).
Results: A total of 108,177 patients were included. The results demonstrate that ND (odds ratio 1.65; $P < 0.001$) and NIDDM (odds ratio 1.75; $P = 0.007$) patients have similar risks of SAE, whereas IDDM (odds ratio 2.79; $P < 0.001$) patients have a greater risk of adverse events, particularly at BMIs greater than 40 kg/m^2.
Discussion: Consistent with previous reports, ND (odds ratio 1.65; $P <$ 0.001) and NIDDM (odds ratio 1.75; $P = 0.007$) morbidly obese patients (BMI > 40 kg/m^2) had an increased odds of SAEs after THA, but for IDDM (odds ratio 2.79; $P < 0.001$) patients this increased odds was notably higher. Although patients with IDDM have increased rates of adverse events compared with ND and NIDDM patients, these findings should not be used to establish strict BMI cutoffs in patients with IDDM. Nonetheless, the results suggest additional factors, such as patient medical history and diabetes control, should be considered when evaluating patients with IDDM for THA.
Level of Significance: Level III

Although total hip arthroplasty (THA) is highly effective in treating advanced hip pathology, complications have consistently been shown to be increased in obese patients.[1-12] Previous studies have found that increasing body mass index (BMI) directly correlates with higher complication rates in joint arthroplasty.[1-12] This phenomenon has led to the recommendation of weight loss and even BMI thresholds by some surgeons in an attempt to improve outcomes.[13,14] Notably, professional societies such as the American Academy of Orthopaedic Surgeons and the American Association of Hip and Knee Surgeons have published guidelines for mediating the risks of surgery in patients with morbid obesity (BMI ≥ 40 kg/m^2) who are considering THA. Such recommendations include delaying surgery, preoperative weight loss, nutrition consultation, and attention to documentation of the risks associated with morbid obesity.[15,16]

Unfortunately, obesity has become an epidemic within the United States, creating a notable challenge to the health care.[17] Over a third of adults are categorized as obese (BMI ≥ 30 kg/m^2) and 6.6% are categorized as morbidly obese (BMI ≥ 40 kg/m^2), recent demographic trends suggest that these numbers are rapidly rising.[18,19] It is well known that a high BMI contributes to lower extremity arthritis.[20,21] With increasing numbers of THA being performed, more are being considered in obese patients.[22]

Diabetes is also associated with increased complication rates after total joint arthroplasty.[7,23,24] Complications that are of increased risk in the diabetic cohort include, but are not limited to, urinary tract infections, surgical site infections, postoperative hemorrhage, and stroke.[7,23] With an increasing number of patients with both obesity and diabetes, a better understanding of the interplay of these risk factors is needed. As demand for joint arthroplasty rises and focus shifts to value-based care, patient optimization has become a focal point for joint arthroplasty.[25] To our knowledge, there have been no publications directly comparing the effect of increasing BMI on patients with different types of diabetes mellitus.

The goal of the current study was to stratify nondiabetic (ND), non–insulin-dependent diabetes mellitus (NIDDM), and insulin-dependent diabetes mellitus (IDDM) patients and study how increasing BMI differentially affects outcomes after THA. It was hypothesized that different rates of adverse events might be observed within each diabetes group.

Methods

Data Source/Study Cohort

The National Surgical Quality Improvement Program (NSQIP) database records and aggregates over 250 variables from representative surgical cases performed at more than 600 participating institutions. Data are collected based on strict protocols and subject to routine audits to control data quality. The NSQIP database records the occurrence of postoperative complications that occurred within 30 days after the operation regardless of discharge status. Outcomes after 30 days are not recorded; thus, long-term outcomes could not be assessed. Our institutional review board has found studies based on this data set to be exempt from review.

The cohort for the current study included those who had undergone THA from 2012 to 2016. These patients were captured using *Current Procedural Terminology* code 27130. Cases noted to involve trauma or emergency surgeries, or that involved a preoperative diagnosis of neoplasm or sepsis were excluded from the study cohort. Such cases were identified based on specifically defined variables in the NSQIP database.

Patient age, sex, race, height, and weight were directly abstracted from the NSQIP database. Height and weight data were used to calculate BMI (weight in kilograms divided by height in meters squared). The American Society of Anesthesiologists' (ASA) physical status classification and preoperative functional status were recorded from the NSQIP database. Functional status was classified into independent and dependent (dependent being defined as partially dependent and totally dependent). Cases with incomplete demographic data described here were excluded.

Patients with diabetes mellitus were identified using a specifically defined NSQIP variable. As per the NSQIP, the diabetes variable is defined as having "Diabetes Mellitus Requiring Therapy with Non-Insulin Agents or Insulin." Patients can be classified into one of three categories: ND patients were defined as patients not having diabetes mellitus, NIDDM patients were defined as diabetic patients not receiving insulin, and IDDM patients were defined as diabetic patients receiving insulin. Characteristics of ND, NIDDM, and IDDM patients were assessed.

Postoperative Outcomes

Individual 30-day postoperative adverse events were aggregated into any adverse events (AAEs), serious adverse events (SAEs), and minor adverse events (MAEs). SAE was defined by the occurrence of any of the following: deep surgical site infection, sepsis, failure to wean, unplanned reintubation, postoperative renal failure, deep vein thrombosis, pulmonary embolism, cardiac arrest requiring cardiopulmonary resuscitation (CPR), myocardial infarction, or stroke. MAE was defined by the occurrence of any of the following: superficial surgical site infection, wound dehiscence, pneumonia, urinary tract infection, or postoperative renal insufficiency. Mortality was distinctly assessed.

Readmission includes patients who were readmitted within 30 days of their procedure. Revision surgeries include patients who had a revision surgery within 30 days of their procedure. AAE was defined by the occurrence of SAE, MAE, death, readmission, or revision surgery.

Statistical Analysis

Demographic information including age, sex, functional health status, ASA score, race, and BMI was aggregated to define the cohorts in each diabetes categories. The occurrence and rates of SAE, MAE, mortality, readmission, revision surgery, and AAE were calculated for patients within each BMI categories. Chi-square analysis was used to determine whether statistically significant differences existed between rates of adverse events when comparing NIDDM and IDDM with ND patients. Statistical significance was defined as $P < 0.05$.

Finally, logistic regressions controlling for age, sex, race, functional status before surgery, and ASA classification were used to isolate confounding patient factors as has been done in other studies using the NSQIP database.[26-28] The odds ratio of SAE in ND, NIDDM, and IDDM patients with BMI ≥ 40 kg/m^2 was compared with a control group of ND patients with a normal BMI (18.5 to 24.9 kg/m^2). This common control group was used to allow for the comparison of the results of this analysis across diabetes groups.

All statistical analyses were performed using SPSS version 25 (IBM Corp).

Results

Patient Cohort

There were 122,570 patient records identified using the NSQIP database. Owing to missing data regarding the occurrence of complications, 14,393 cases (11.7%) were excluded because they could not be included in the analysis, leaving 108,177 cases for analysis. These 14,393 excluded cases had a similar proportion of ND (87%), NIDDM (9%), and IDDM (4%) patients to our study cohort. In our study cohort, 95,564 patients (88%) had ND, 9,728 patients (9%) had NIDDM, and 2,885 patients (3%) had IDDM (Figure 1).

Table 1 demonstrates the patients' characteristics of the ND, NIDDM, and IDDM groups. Rates for the different categories of age, sex, functional status, ASA, race, and BMI are defined. Of note, BMI ≥ 40 kg/m^2 was noted in 6.4% of the ND patients, 14.7% of the NIDDM patients, and 17.8% of the IDDM patients.

Adverse Events

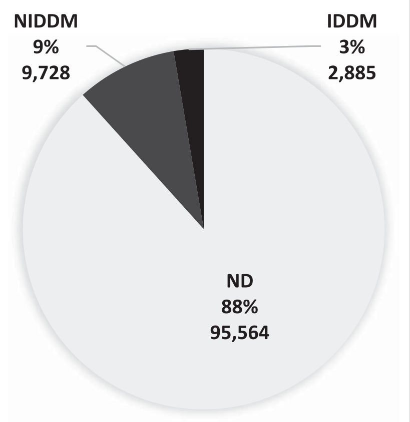
The occurrence rates of SAE, MAE, mortality, readmission, revision surgery, and AAE are shown in Table 2. Those with NIDDM and IDDM were at a greater overall risk of SAE, MAE, readmission, revision surgery, and AAE. In addition, those with IDDM were also at a greater overall risk of mortality.

Using a control group of ND patients with a normal BMI (18.5 to 24.9 kg/m^2), odds ratios of SAEs for a BMI greater than 40 kg/m^2 were calculated in ND, NIDDM, and IDDM patients (Table 3). The results demonstrate that ND (odds ratio 1.65; $P < 0.001$) and NIDDM (odds ratio 1.75; $P = 0.007$) patients have similar risks of SAE, whereas IDDM (odds ratio 2.79; $P < 0.001$) patients have a greater risk of adverse events, particularly at BMIs of 40 kg/m^2.

Discussion

Obesity and diabetes are becoming more prevalent in the THA cohort and have been linked to increased surgical complications.[1-12,23,24]

Figure 1



Pie chart showing the comparison of cohort sizes between nondiabetic, non–insulin-dependent diabetes mellitus, and insulin-dependent diabetes mellitus patients. IDDM = insulin-dependent diabetes mellitus, ND = nondiabetic, NIDDM = non–insulin-dependent diabetes mellitus.

Given the increased rates of THA surgeries and the morbidity associated with patients experiencing complications within this cohort, patient selection and optimization have become important points of discussion. Professional societies, including the American Academy of Orthopaedic Surgeons and the American Association of Hip and Knee Surgeons, have suggested considerations such as delaying surgery, preoperative weight loss, nutrition consultation, and attention to documentation of the risks associated with morbid obesity (those with a BMI greater than 40 kg/m^2).[15,16] Although there is some variability with BMI cutoffs, the message has been mirrored by others.[3,10,29]

A notable finding in the current study was that ND and NIDDM patients were found to have similar risks at a BMI of 40 kg/m^2. The different rates of complications between NIDDM and IDDM have been observed in previous studies of orthopaedic surgery patients. Previous studies have attributed these differences to the natural course

Table 1

ND, NIDDM, and IDDM Patient Demographics

	ND		NIDDM		IDDM	
	Number	Percent	Number	Percent	Number	Percent
n = 108,177	95,564	88.3	9,728	9.0	2,885	2.7
Age (yr)						
≤40	2,633	2.8	53	0.5	23	0.8
41-50	7,594	7.9	410	4.2	162	5.6
51-60	24,153	25.3	1,998	20.5	606	21.0
61-70	32,152	33.6	3,735	38.4	1,121	38.9
71-80	21,174	22.2	2,689	27.6	742	25.7
>80	7,858	8.2	843	8.7	231	8.0
Sex						
Male	42,557	44.5	4,916	50.5	1,516	52.5
Female	53,007	55.5	4,812	49.5	1,369	47.5
Functional status						
Independent	94,193	98.6	9,535	98.0	2,792	96.8
Dependent	1,371	1.4	193	2.0	93	3.2
ASA						
1	4,204	4.4	20	0.2	0	0
2	55,376	57.9	3,007	30.9	501	17.4
3	34,652	36.3	6,368	65.5	2,171	75.3
4+	1,332	1.4	333	3.4	213	7.4
Race						
White	78,468	82.1	2,237	77.5	7,566	77.8
Black	7,004	7.3	405	14.0	1,115	11.5
Asian	1,399	1.5	35	1.2	192	2.0
American Indian	391	0.4	10	0.3	47	0.5
Pacific Islander	246	0.3	14	0.5	41	0.4
Unknown/not reported	8,056	8.4	184	6.4	767	7.9
BMI (kg/m^2)						
<18.5	801	0.8	20	0.2	6	0.2
18.5-24.9	19,778	20.7	740	7.6	195	6.8
25.0-29.9	33,009	34.5	2,387	24.5	668	23.2
30-39.9	35,910	37.6	5,146	52.9	1,503	52.1
40-49.9	5,514	5.8	1,305	13.4	471	16.3
≥50.0	552	0.6	130	1.3	42	1.5

ASA = American Society of Anesthesiologists, BMI = body mass index, ND = nondiabetic, NIDDM = non–insulin-dependent diabetes mellitus, IDDM = insulin-dependent diabetes mellitus

of illness and difficulty achieving glycemic control in patients with IDDM compared with patients with NIDDM.[30,31] Patients with IDDM are at a higher risk of developing a variety of comorbidities compared with NIDDM and ND patients. In addition, patients with IDDM are more likely to have poor glycemic control, resulting in increased rates of renal and cardiovascular disease earlier in life.[30] Exogenous insulin also causes rapid fluctuations in glucose levels that can lead to severe hypoglycemia and hyperglycemia, especially in the perioperative setting.

Using the odds ratios of SAEs to inform surgical candidacy has strong clinical utility because SAEs have the greatest effect on the patient and healthcare system. Such complications include deep surgical site infection, sepsis, failure to wean, unplanned reintubation, postoperative renal failure,

Table 2

Rates of Adverse Events in ND, NIDDM, and IDDM Patients

	ND		NIDDM			IDDM		
	Number	Percent	Number	Percent	*P* Value[a]	Number	Percent	*P* Value[a]
Adverse events								
SAE	1,107	1.2	166	1.7	**<0.001**	88	3.1	**<0.001**
MAE	1,714	1.8	230	2.4	**<0.001**	115	4.0	**<0.001**
Mortality	87	0.1	10	0.1	0.863	8	0.3	**0.003**
Readmission	3,071	3.2	432	4.4	**<0.001**	183	6.3	**<0.001**
Revision surgery	1,789	1.9	228	2.3	**<0.001**	95	3.3	**<0.001**
AAE	5,147	5.4	688	7.1	**<0.001**	300	10.4	**<0.001**

IDDM = insulin-dependent diabetes mellitus, MAE = minor adverse event, ND = nondiabetic, NIDDM = non–insulin-dependent diabetes mellitus, SAE = serious adverse event
[a] Chi-square analysis demonstrated a statistically significant difference when compared with ND patients.
$P < 0.05$ are in bold to denote significance.

deep vein thrombosis, pulmonary embolism, cardiac arrest requiring CPR, myocardial infarction, or stroke. The current data suggest that setting a single BMI cutoff for proceeding with THA may be overly simplistic, and different thresholds may be appropriate for different subcohorts such as patients with IDDM.

Increased postoperative complications in obese patients have been reported by many studies, driving the development of surgical BMI thresholds.[1-12] Previous studies that stratify BMI have found that higher BMI leads to increased complications. Such studies have proposed BMI thresholds based on the point where adverse events tend to rise sharply. Generally, this has been reported to be most pronounced at a BMI of 40 kg/m^2, thus leading to the implementation of this value as an indication of excessive surgical risk.

The current study supports the earlier quoted BMI threshold for THA being 40 kg/m^2 for ND and NIDDM patients.[4,9,11,12,32] The odds ratio of SAE for a BMI greater than 40 kg/m^2 for ND and NIDDM patients was similar, whereas the odds ratio of SAE in patients with IDDM was notably greater. The fact that the notably smaller subcohort of IDDM (only 2.7% of the cohort) could behave differently and be "washed out" in the larger ND and NIDDM is not surprising but is highlighted by the presented analysis. The difference in the odds ratio between diabetic groups indicates that further studies are needed to determine how to mitigate the risk of adverse outcomes in patients with IDDM requiring THA.

Table 3

Odds Ratio of SAEs for Patients With BMI ≥ 40 kg/m^2 Compared With a Control Group of ND Patients With a Normal BMI (18.5 to 24.9 kg/m^2)

Diabetes Status	Odds Ratio of SAE ± 95% CI
ND	1.65 (1.26–2.16) ($P < 0.001$)
NIDDM	1.75 (1.17–2.61) ($P = 0.007$)
IDDM	2.79 (1.74–4.45) ($P < 0.001$)

BMI = body mass index, IDDM = insulin-dependent diabetes mellitus, ND = nondiabetic, NIDDM = non–insulin-dependent diabetes mellitus, SAE = serious adverse event

Further complicating risk stratification by BMI are the associated comorbidities that may compound surgical risk. Notably, obesity and diabetes often exist concomitantly as elements of the metabolic syndrome. In fact, a BMI above 40 kg/m^2 is associated with more than six times higher risk for diabetes.[32] The multivariate analysis used to determine the odds ratio of SAE in the current study worked to account for such covariate variables.

Risk stratification requires a holistic approach with careful assessment of comorbidities and honest conversation regarding expectations and real surgical risk with the patient. Some studies have noted very good clinical results in the obese cohort, suggesting that a strict universal cutoff could unnecessarily exclude certain obese patients.[33-36] It is incumbent on the orthopaedic surgeon to work with patients to modify risk factors when possible to optimize short-term and longer term outcomes, which includes counseling patients on weight loss and diabetic control.

Our study is the first to stratify risks of obesity in THA with respect to types of diabetes mellitus. However, our data should be interpreted with attention to its limitations, primarily stemming from its retrospective database design. First, we grossly categorized diabetic status as NIDDM and IDDM, which does not consider heterogeneity in glycemic control within groups. Previous literature suggests that most patients with IDDM have type 2 diabetes with poor glycemic control.[37] However, without information about each patient's type of diabetes and HbA1C level at the time of surgery, the characteristics of the IDDM group cannot be determined with certainty. Thus, although glycemic control could be a contributing factor to the increased risk of complications, other unknown factors may also have a role. Second, despite quality control of NSQIP's data, it is difficult to assess the potential bias involved in data collection methods that may involve incomplete documentation or miscoding. Furthermore, the current study can only comment on short-term outcomes, as outcomes are only assessed out to 30-day postoperative adverse events in NSQIP. Owing to this limitation, crucial long-term joint-specific outcomes such as late infections, aseptic loosening, and clinical/joint-specific metrics could not be assessed in this timeframe. Finally, not all confounders can be accounted for in the multivariate analysis because pertinent data such as hemoglobin A1C values are not available in the NSQIP database; however, ASA class and functional health status were useful controls for patients' quality of health before their operation.

In conclusion, this study highlights the increased 30-day complication rates after THA in patients with IDDM and the effect of high BMI within each of our cohorts. Consistent with clinical reports, ND (odds ratio 1.65; $P < 0.001$) and NIDDM (odds ratio 1.75; $P = 0.007$) morbidly obese patients (BMI > 40 kg/m^2) had increased odds of SAEs after THA, but for IDDM (odds ratio 2.79; $P < 0.001$) patients this increased odds was notably higher. Although patients with IDDM have increased rates of adverse events compared with ND and NIDDM patients, these findings should not be used to establish strict BMI cutoffs in patients with IDDM. Nonetheless, the results suggest additional factors, such as patient medical history and diabetes control, should be considered when evaluating patients with IDDM for THA. These data serve to define the relationship between obesity, diabetes, and early postoperative complications after THA, and may be beneficial to patient education, risk-benefit analyses, and clinical decision making.

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