Original Research

Metabolic Syndrome Is Associated With Higher Risk of Wound Complications After Total Hip Arthroplasty

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ABSTRACT

Background: Obesity is prevalent among patients undergoing total hip arthroplasty and has been associated with the risk of wound complications, particularly when an anterior approach is used. However, most studies have focused on obesity defined by the body mass index (BMI), without considering the metabolic effects of adiposity. Thus, in this study, we investigated the independent effects of the BMI and metabolic syndrome on wound complications after total hip arthroplasty.

Methods: Among 804 consecutive patients undergoing total hip arthroplasty between October 2013 and July 2016, we evaluated the associations between obesity (BMI $\geq$30 mg/kg^2), metabolic syndrome (defined by the National Cholesterol Education Program Adult Treatment Panel III guidelines), and wound complication (defined as documented wound dehiscence, drainage, erythema, hematoma, infection, or seroma) over a 1-year follow-up period. We used Cox proportional hazards models adjusting for demographics, smoking status, and hospital length of stay.

Results: Patients' mean age at time of surgery was 62.0 $\pm$ 11.9 years. Forty-seven percent were male, 27.9% were obese, and 11.6% met the definition for metabolic syndrome. Metabolic syndrome was associated with a 4-fold higher risk of wound complication (95% confidence interval: 1.4-11.1) after adjusting for all covariates including the BMI. In unadjusted analysis, obesity was associated with a higher risk of wound complication (hazard ratio: 2.8, 95% confidence interval: 1.3-6.2). However, obesity was not associated with the risk of wound complication after adjusting for the metabolic syndrome ($P = .16$).

Conclusions: Metabolic syndrome, but not obesity, defined by a BMI $\geq$30, was associated with wound complications, suggesting that metabolic effects of adiposity may represent a distinct risk factor in the development of wound complications from a higher BMI alone.

Introduction

Approximately 35% of American adults meet the definition of obesity with a body mass index (BMI) of 30 kg/m^2 or higher [1]. An estimated 300,000 individuals in the United States undergo total hip arthroplasty (THA) annually [2], with more than 50% of these individuals classified as obese [3]. Obesity has been associated with an elevated risk of wound complications in THA [4-6] and total knee arthroplasty [7,8]. Thus, the high prevalence of obesity in patient populations that underwent THA raises a concern regarding wound complication prevention and successful postsurgical recovery.

Obesity is of special interest in the direct anterior approach to THA because it is thought that abdominal panniculus overhanging the surgical wound may increase the risk of wound complication [9]. Numerous reports suggest that the anterior approach to THA alone increases the risk of wound complications [10,11], with one study demonstrating up to a 7-fold higher risk as compared with the posterior approach [12]. This risk is thought to be further increased in obese patients [9,13]. As such, obesity, and especially morbid obesity (BMI $\geq$40), is a relative contraindication for utilization of the anterior approach for THA [14].

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Interestingly, not all studies have shown higher risk of wound complications with a higher BMI [15,16]. Moreover, some studies demonstrate an equal or higher rate of wound complications with the posterior approach, where overlying panniculus is not a concern, than the anterior approach [13,17]. Together, these studies indicate that the abdominal panniculus mechanism may not fully explain the association between the anterior approach to THA, obesity, and wound complications.

One possible explanation for the inconsistency between BMI and wound complication rates is that obesity is often accompanied by a constellation of metabolic abnormalities that constitute the metabolic syndrome [18]. Metabolic syndrome, defined as at least 3 of 4 component comorbidities (obesity, dyslipidemia, hypertension, and diabetes), has been associated with increased major complications after total joint arthroplasty [19] and specifically with increased pulmonary embolism after THA or total knee arthroplasty [20]. Another study using slightly different criteria for metabolic syndrome, defined as obesity plus any 2 component comorbidities (hyperlipidemia, hypertriglyceridemia, hypertension, or diabetes), also found that metabolic syndrome increased the risk of postoperative complication after total joint arthroplasty than a higher BMI alone [21]. The risk of these perioperative complications may be due to the contributions of adipokines, for example, tumor necrosis factor, leptin, resistin, and plasminogen activator inhibitor, as they have been shown to contribute to prothrombotic and proinflammatory states and are thought to be elevated in metabolic syndrome [22]. In addition, high glucose flux across endothelial cell membranes in the setting of elevated plasma glucose has been implicated in the formation of oxygen radicals that initiate an inflammatory cascade [23], and hyperglycemia may, therefore, function as a mediator in the relationship between metabolic syndrome and perioperative complication. Thus, it is important to evaluate metabolic syndrome as an independent contributor to wound complications after THA and to consider its component comorbidities.

Although obesity is frequently associated with metabolic syndrome, some obese individuals have normal metabolic profiles. Conversely, not all individuals who have metabolic syndrome are obese. In particular, metabolically healthy obese individuals have an elevated BMI but do not demonstrate features of metabolic dysregulation and constitute 31.7% of Americans [24,25]. On the other hand, approximately 23.5% of Americans display metabolic profiles typically associated with obesity but are of normal weight [25]. The identification of these different obesity phenotypes suggests that metabolic adiposity and an elevated BMI can and should be evaluated as distinct risk factors, as it is not known whether individuals with metabolic syndrome alone have the same risk as those with only an elevated BMI or how either of these populations compares with individuals who exhibit both metabolic dysregulation and an elevated BMI.

The purpose of this study, therefore, was to examine the effects of metabolic syndrome and obesity on wound complications during the 1-year period after THA. Secondary analyses evaluated whether the relationship between metabolic syndrome, obesity, and wound complications varied based on surgical approach.

Material and methods

Study population

All adult patients aged 18 years or older who underwent THA (Current Procedural Terminology 27130) within a single university health system with electronic medical record documentation for at least 1 year after their surgery were included in this study (October 28, 2013-July 13, 2016). Patients were excluded if their surgery was not performed by an arthroplasty-trained surgeon, yielding a study population of 826 patients. The height or weight required to calculate the BMI was not available in 22 patients, yielding a final sample size of 804. Institutional review board approval was obtained before initiating this study.

Assessment of variables

All variables were obtained from the electronic medical record via the institutional Clinical Data Warehouse for Research. All data used in this study were structured; none required abstraction from patient charts. Preoperative variables included the height, weight, blood pressure, documented past medical diagnoses, documented medication inventory, and most recent laboratory measurements (fasting glucose, hemoglobin A1C [HbA1C], C-reactive protein, creatinine, hematocrit, methicillin-resistant Staphylococcus colonization status) up to 1 year before the date of surgery. Of note, not all laboratory values were available for all patients. The number of patients with available measures is indicated in Table 1. Operative and perioperative variables included the date of surgery, time of surgery, operative time, approach, surgeon, type of anesthesia, laterality, American Society of Anesthesiologists classification, anticoagulation used, length of stay, and discharge disposition. The following diagnoses in the 1-year postoperative period were also ascertained: wound complications (defined as a composite outcome comprised of any instance of dehiscence, drainage, erythema, hematoma, infection, or seroma), venous thromboembolism (including deep venous thrombosis and pulmonary embolism), stroke, myocardial infarction, urinary tract infections, all infections, and hip dislocation (International Classification of Diseases, Ninth Revision codes for all diagnoses are listed in Table 2).

Definition of primary explanatory variables and outcome variable

The BMI was calculated as the body weight (kg) divided by the height squared (m^2). We defined obesity as a BMI $\geq$30 kg/m^2 and analyzed it as a dichotomous variable.

Metabolic syndrome was defined according to a modified version of the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATPIII) guidelines [26]. Although there are several other criteria used to define metabolic syndrome, the NCEP-ATPIII guidelines were selected because they are one of the most widely used criteria and use measurements and laboratory values that are readily available to physicians and therefore have the most clinical utility [27]. The defining levels by these guidelines are waist circumference >102 cm in men or 88 cm in women, triglycerides $\geq$150 mg/dL, high-density lipoprotein (HDL) < 40 mg/dL in men or <50 mg/dL in women, blood pressure $\geq$130/85, and fasting glucose $\geq$110 mg/dL. In this study, treatment of these conditions was also considered as a surrogate for these criteria because appropriate treatment should normalize detectable levels of these parameters. Specifically, the use of gemfibrozil was considered as a surrogate marker of elevated triglycerides, the use of a statin was considered a marker of dyslipidemia, the use of an antihypertensive medication was considered equivalent to an elevated blood pressure, and the use of an oral hypoglycemic or insulin was considered equivalent to elevated fasting glucose. In addition, documented diagnoses of hypertriglyceridemia, hyperlipidemia, hypertension, or hyperglycemia/diabetes were also considered to be equivalent to meeting a defining level. Of note, waist circumference was not available because it is not a routinely measured variable in our clinical practice. Patients meeting any 3 of the remaining 4 criteria were considered to have metabolic syndrome.

Table 1
Participant characteristics by wound complication status.

Characteristic	N	No wound complication (n = 779)	Wound complication (n = 25)	P-value
Age (y)	804	62.0 ± 11.8	64.3 ± 14.3	.33
Gender (% male)	804	47.5	36.0	.31
Weight (kg)	804	80.5 ± 18.3	82.2 ± 18.5	.65
Height (m)	804	1.70 ± 0.1	1.69 ± 0.1	.43
BMI (kg/m²)	804	27.6 ± 5.1	28.9 ± 6.4	.21
Systolic blood pressure (mmHg)	792	131.2 ± 15.3	130.6 ± 14.8	.85
Laboratory values				
Glucose (mg/dL)	668	96.7 ± 16.9	104.5 ± 38.4	.06
Hematocrit (%)	677	41.5 ± 3.6	40.0 ± 2.8	.07
Creatinine (mg/dL)	669	0.89 ± 0.4	0.88 ± 0.2	.85
C-reactive protein (mg/dL)	116	0.40 (0.20, 0.80)	0.40 (0.20, 0.70)	.92
Hemoglobin A1C (%)	182	5.7 ± 0.6	6.2 ± 0.8	.003
HDL (mg/dL)	174	60.0 (49.0, 73.0)	64.0 (43.0, 80.5)	.89
Triglycerides (mg/dL)	174	106.0 (77.5, 145.5)	106.0 (81.5, 142.5)	.88
Preoperative medication use				
Antibiotic (%yes)	804	12.5	16.0	.54
Bisphosphonate (%yes)	804	3.0	4.0	.54
NSAID (%yes)	804	55.5	12.3	.54
Vitamin D (%yes)	804	24.3	24.0	1.00
Antidepressant (%yes)	804	15.8	24.0	.27
Diabetes medication (%yes)	804	6.7	12.0	.24
Preoperative diagnoses				
Diabetes (%yes)	804	2.1	20.0	.04
Hypertension (%yes)	804	30.0	32.0	.83
Hyperlipidemia(%yes)	804	27.0	52.0	.01
Metabolic syndrome (%yes)	804	0.3	0.0	1.00
Coronary artery disease (%yes)	804	5.5	16.0	.05
Peripheral vascular disease (%yes)	804	0.3	4.0	.09
Operative characteristics				
Operative time (min)	803	166.9 ± 38.8	169.9 ± 33.5	.70
Length of stay (d)	804	2.1 ± 1.2	3.9 ± 4.8	<.001
SNF discharge (%yes)	804	13.7	20.0	.38
ASA class	794	2 (2, 3)	2 (2, 3)	.90
Approach (%posterior)	804	54.9	44.0	.31

ASA, American Society of Anesthesiologists; NSAID, nonsteroidal anti-inflammatory drugs.
Mean ± standard deviation for normally distributed variables, the median (25th percentile and 75th percentile) for nonparametric variables, the percentage for categorical variables.

The outcome variable in the primary analysis, presence of any wound complication, was defined as any documentation of wound dehiscence, wound drainage, wound erythema, wound hematoma, wound infection, or wound seroma within 1 year after THA. We classified wound complication as yes/no based on the presence of the criteria listed in Table 1.

Statistical methods

Descriptive statistics were used to compare patients without and with wound complications using *t*-tests for continuous variables and chi-square tests for categorical variables. For nonparametric continuous variables, a Mann-Whitney *U*-test was applied. To select covariates for our survival analysis, we first evaluated univariate associations between potential risk factors and wound complications using logistic regression. We subsequently used Cox proportional hazards analysis with sequential models accounting for covariates to assess the risk of obesity and metabolic syndrome with wound complication over the 1-year follow-up period. Model 1 was the unadjusted association. Model 2 adjusted for age and gender. Model 3 adjusted for smoking status, as smoking is a widely recognized risk factor for wound healing [28]. Model 4 adjusted for the length of stay, which was found on our initial univariate analysis to be associated with wound complication (odds ratio: 1.3, 95% confidence interval [CI] 1.10-1.44, *P* = .001). Finally, the fully adjusted model 5 included the opposite primary explanatory variable (eg, obesity in the metabolic syndrome analysis and metabolic syndrome in the obesity analysis).

Table 2
ICD-9 codes of diagnoses in the 1-y postoperative period.

Diagnosis	ICD-9 code
Wound complication	890 (wound dehiscence)
	879.8 (wound drainage)
	695.9 (erythema)
	924 (thigh hematoma)
	924.01 (hip hematoma)
	924.9 (hematoma)
	924.5 (leg hematoma)
	998.12 (hematoma complicating a procedure)
	909.3 (postoperative wound infection, sequela)
	958.3 (wound infection)
	998.59 (wound infection after surgery)
	998.13 (wound seroma)
Venous thromboembolism	453.4 (DVT)
	453.42 (DVT of bilateral lower extremities)
	415.13 (acute saddle pulmonary embolism)
	415.19 (pulmonary embolism)
Stroke	434.91 (stroke)
	435.9 (Stroke or TIA)
Myocardial infarction	410.1 (Anterior wall myocardial infarction)
	410.4 (inferior wall)
	410.7 (NSTEMI)
	410.9 (STEMI)
Prosthetic hip infection	909.3 (prosthetic hip infection, sequela)
	996.66 (prosthetic joint infection, initial encounter)
Hip dislocation	835

DVT, deep vein thrombosis; ICD-9, International Classification of Diseases, Ninth Revision; NSTEMI, non-ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.
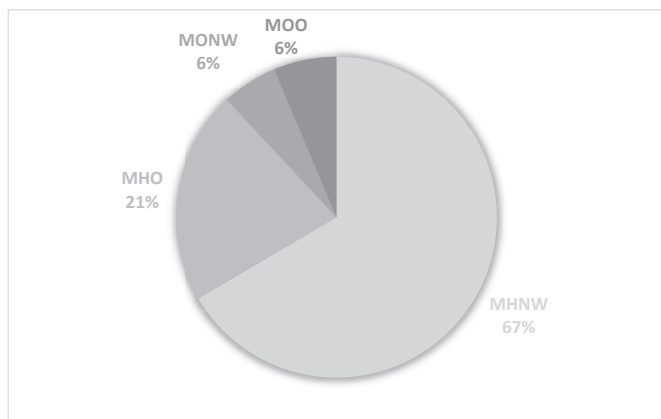
Figure 1. Obesity phenotypes in the study population. MHNW, metabolically healthy, normal weight; MHO, metabolically healthy, obese; MONW, metabolically obese (metabolic syndrome), normal weight; MOO, metabolically obese (metabolic syndrome), obese.

Secondary analyses evaluated the association between diabetes (defined as HbA1C $\geq$ 6.5%, fasting glucose $\geq$110 mg/dL, past medical history of diabetes, or history of oral hypoglycemic or insulin use in the 30 days before surgery) and wound complication over the 1-year follow-up period using Cox proportional hazards models. Among the individuals with metabolic syndrome, we also evaluated the relative risk ratio of wound complication without and with the component comorbidities of the metabolic syndrome (diabetes, elevated triglycerides, low HDL, and hypertension).

We evaluated associations of obesity and metabolic syndrome with secondary outcomes, such as venous thromboembolism, stroke, myocardial infarction, urinary tract infections, and hip dislocation using logistic regression.

P-values less than .05 were considered statistically significant. All analyses were performed using SPSS, version 26 (IBM Corp. Released 2019. IBM SPSS Statistics for Macintosh, Version 26.0. Armonk, NY: IBM Corp.).

Results

Participant characteristics

Between October 28, 2013 and July 13, 2016, 826 patients underwent THA by trained arthroplasty surgeons within a single university health system. Among the 804 patients with available anthropometric measures to calculate the BMI, the mean age was 62.0 $\pm$ 12.0 years. Forty-seven percent of these patients were male, 27.9% were obese (BMI $\geq$30), and 11.9% met the definition for metabolic syndrome. Approximately 21.5% of the study population was obese but had normal metabolic profiles, 5.6% had metabolic syndrome but was of normal weight, and 6.3% both had metabolic syndrome and were obese (Fig. 1).

The most common type of anesthesia was general (57.6%), followed by spinal anesthesia (30.7%). Approximately 1.9% of cases were bilateral, and 48.4% were of the right hip only. The operative time was 167.0 $\pm$ 38.6 minutes, and the length of stay was 2.2 $\pm$ 1.5 days. The prevalence of wound complication across the 804 patients was 3.1% (25 patients).

Demographic, baseline anthropometric measures and the preoperative medication use were not different between patients who developed a wound complication after THA and those who did not (Table 1). Patients who developed wound complications had a higher HbA1C (*P* = .003) and were 17.9% more likely to have a documented diagnosis of diabetes in the medical record (*P* = .02). They were also 27% more likely to have documented diagnoses of hyperlipidemia (*P* = .006).

Patients who developed a wound complication after THA stayed 2.1 days longer after their surgery than those who had no wound complications (*P* < .001). There was no difference between these patients in the discharge disposition, operative time, the American Society of Anesthesiologists —classification, or surgical approach (Table 1).

Obesity and wound complications

The incidence rate for wound complication was 8.7 per 100,000 person-days (Table 3). There was no difference in incidence of wound complication between the anterior approach (3.9%) and posterior approach (2.5%, *P* = .312).

The wound complication risk was 2.8-fold higher in obese vs nonobese individuals (95% CI: 1.3-6.2, Table 3) in unadjusted analysis. However, this effect was attenuated after adjusting for metabolic syndrome (hazard ratio [HR]: 2.0, 95% CI: 0.8-5.4, *P* = .17).

The prevalence of obesity was higher among those who underwent the anterior approach (34.0%) than among those who underwent the posterior approach (22.8%, *P* < .001). However, there was no difference in the wound complication risk in obese compared with nonobese individuals undergoing the anterior (HR: 2.3, 95% CI: 0.6-9.1, *P* = .22) or posterior approach (HR: 1.8, 95% CI: 0.4-8.0, *P* = .44).

Metabolic syndrome and wound complications

In unadjusted analysis, metabolic syndrome was associated with a 3.9-fold higher risk of wound complication (95% CI: 1.6-8.3). After adjustment for all covariates, including obesity status, the wound complication risk was 4-fold higher in individuals defined as having metabolic syndrome than in those without metabolic syndrome (95% CI: 1.4-11.1, Table 4). Subgroup analysis demonstrated a 5.4-fold higher risk of wound complications in posterior approach patients with metabolic syndrome than in those without

Table 3

Unadjusted and sequentially adjusted hazard ratio of wound complications associated with obesity defined as a BMI $\geq$30 for all-comers, anterior hips only, and posterior hips only.

Incident wound complication	Obesity (BMI $\geq$30) Hazard ratio (95% CI)					
	N	All hips	N	Anterior only	N	Posterior only
Obesity prevalence (%)		27.9		34.0		22.8
Wound complication rate per 100,000 person-days after surgery		8.7		10.8		7.0
Unadjusted	804	2.8 (1.3-6.2)	365	2.6 (0.9-7.5)	439	2.8 (0.9-9.3)
Age, sex adjusted	804	2.9 (1.3-6.4)	365	2.5 (0.9-7.4)	439	2.8 (0.9-9.4)
Fully adjusted[a], including metabolic syndrome	683	2.0 (0.8-5.4)	307	2.4 (0.6-9.1)	376	1.8 (0.4-8.0)

[a] Covariates in the fully adjusted model included the following: the age, sex, smoking status, length of stay, metabolic syndrome.

Table 4
Unadjusted and sequentially adjusted hazard ratio of wound complications associated with metabolic syndrome defined by at least 3 of the NCEP-ATPIII criteria for metabolic syndrome for all-comers, anterior hips only, and posterior hips only.

Incident wound complication	N	Metabolic syndrome Hazard ratio (95% CI)				
		All hips	N	Anterior only	N	Posterior only
Metabolic syndrome prevalence (%)		11.9		13.0		11.0
Unadjusted	804	3.9 (1.6-8.3)	365	4.2 (1.4-12.5)	439	2.9 (0.8-10.9)
Age and sex adjusted	804	3.5 (1.5-8.1)	365	4.4 (1.5-13.1)	439	2.5 (0.7-9.7)
Fully adjusted[a], including obesity	683	4.0 (1.4-11.1)	307	3.6 (0.9-14.1)	376	5.4 (1.1-26.9)

[a] Covariates in the fully adjusted model included the following: the age, sex, smoking status, length of stay, and obesity.

metabolic syndrome (95% CI: 1.1-26.9), regardless of obesity status. Although in unadjusted analysis there was a higher risk of wound complications with metabolic syndrome among individuals who underwent the anterior approach to THA (HR: 4.2, 95% CI: 1.4-12.5), this effect was attenuated after adjustment for the obesity status (HR: 3.6, 95% CI: 0.9-14.1). The prevalence of metabolic syndrome was not different between patients undergoing the anterior approach (12.3%) and those undergoing the posterior approach (11.6%, *P* = .757).

Component comorbidities of metabolic syndrome and wound complications

Among the 93 individuals with metabolic syndrome, there was a 2.3-fold higher cumulative risk of wound complication among those with diabetes than those without, noting a small sample size with only 7 individuals who had a wound complication and both metabolic syndrome and diabetes. In addition, of the patients with available laboratory measures who had both wound complications and metabolic syndrome, 100% had low HDL and 87.5% were hypertensive. Only 40% of those with wound complications and metabolic syndrome had elevated triglycerides.

Despite the higher risk of wound complication associated with diabetes among individuals with metabolic syndrome and a higher prevalence of diabetes among the population (15.9%) compared with the prevalence of metabolic syndrome (11.9%), there was no significant higher wound complication risk associated with diabetes among the overall population (HR: 2.1, 95% CI: 0.8-5.7).

Secondary outcomes

There was no significant association between either obesity or metabolic syndrome and the secondary outcomes of dislocation, prosthetic joint infection, venous thromboembolism, stroke, myocardial infarction, and urinary tract infection (Table 5).

Discussion

Patients with metabolic syndrome had a 4-fold higher risk of wound complication after THA, independent of the BMI, than patients without metabolic syndrome. Interestingly, patients with a higher BMI had a 2.8-fold higher risk for wound complications in initial analyses, but this effect was attenuated after adjustment for metabolic syndrome. Together, these findings suggest that the metabolic effects of adiposity are distinct from and may potentially contribute more to wound complication risks than obesity (BMI $\geq$30 kg/m^2) alone.

Previous studies of wound complication in THA and obesity have focused on the BMI without considering the metabolic aspect of adiposity [4-6,9,10,13,15,16,29-33]. Some of these studies failed to show a difference in postoperative complications after THA between obese and nonobese patients [15,16]. Our results, which also find no association between the BMI and wound complications after accounting for metabolic syndrome, are in accordance with these previous studies. We speculate that, if adjusted for metabolic syndrome, the remaining studies would similarly demonstrate attenuated or null associations between the higher BMI and wound complications because obesity and metabolic syndrome frequently but do not always co-occur. Those studies that found positive associations between the BMI and wound complication may have included a large number of patients with an elevated BMI and coincident metabolic syndrome, where metabolic syndrome was the actual risk factor for wound complication but labeled as an "elevated BMI." While purely speculative, these studies evaluating obesity as defined by an elevated BMI without considering metabolic syndrome status may not adequately address the underlying metabolic dysregulation that results in a higher risk of wound complications.

Interestingly, among those with metabolic syndrome, there was a 2.3-fold higher cumulative risk of wound complication among patients with diabetes than those without, which suggests that hyperglycemia could potentially mediate the association between metabolic syndrome and wound complication. It is important to note, however, that this finding does not mean that diabetes/hyperglycemia is an independent cause of increased wound complications in the absence of metabolic syndrome, as there was no significant association between diabetes and wound complication when considering patients both without and with metabolic syndrome. Although it is theoretically possible that the number of wound complications was too small in our sample to detect a subtle

Table 5
Unadjusted odds ratio (95% confidence interval) of secondary outcomes associated with obesity and metabolic syndrome.

Outcome	Prevalence (# of events)	Obesity (BMI$\geq$30) (n = 804)	Metabolic syndrome (n = 804)
Hip dislocation	1.0% (8)	0.4 (0.1-3.6)	N/A[a]
Prosthetic joint infection	1.5% (12)	1.3 (0.4-4.4)	0.7 (0.1-5.2)
Venous thromboembolism	1.7% (14)	0.8 (0.2-2.8)	2.3 (0.6-8.3)
Stroke	0.7% (6)	N/A[b]	3.8 (0.8-20.7)
Myocardial infarction	1.2% (10)	0.6 (0.1-3.1)	1.9 (0.4-8.9)
Urinary tract infection	3.8% (31)	0.6 (0.3-1.6)	1.1 (0.4-3.3)

[a] Could not be computed. No patient who had metabolic syndrome had a dislocation.
[b] Could not be computed. No patient who was obese had a stroke.

effect of diabetes, that there was a significant association with metabolic syndrome despite a lower prevalence of metabolic syndrome as compared with diabetes indicates that the metabolic syndrome may have a stronger role as a risk factor for wound complications. As has been reported in the literature on metabolic syndrome, hyperglycemia, and coronary heart disease, metabolic syndrome and hyperglycemia strongly overlap but are not conceptually equivalent, and metabolic syndrome captures nondiabetic subjects with an increased cardiovascular disease risk [34]. Similarly, while many individuals with metabolic syndrome are hyperglycemic, metabolic syndrome likely captures individuals at an increased wound complication risk who are euglycemic.

Subgroup analysis by a surgical approach further supports our main findings that the metabolic effects of adiposity should be considered before surgery vs relying on the BMI alone. It has been proposed that the anterior approach is associated with a higher risk of wound complications than the posterior approach because a higher BMI results in abdominal panniculus overhanging the surgical wound, which creates a moist environment for bacterial growth [9]. We did not find an association between obesity and wound complications among patients who underwent the anterior approach in this study. It is possible that the sample of patients who underwent the anterior approach was too small to detect an association where an association may exist. A larger analytic sample would be needed to determine if a subtle association is present.

Specialized postoperative protocols for obese patients instituted by our surgeons may also explain why the BMI was not associated with wound complications in this study. Although we have found no specific recommendations in the literature regarding specialized follow-up for obese patients, based on the literature-reported association between obesity, wound complications, and the anterior approach, obese patients who undergo the anterior approach at our institution are frequently given a shorter interval at the first postoperative follow-up visit (2 weeks instead of 1 month). They also often receive special attention to their wound, such as a continuous negative-pressure incision closure device. Thus, the differential risk between obese and nonobese individuals may be diminished by our protocols. This may also explain why metabolic syndrome was associated with wound complications among patients who had undergone the posterior approach, who do not receive short interval follow-up or special wound care based on the obesity status, but not the patients who had undergone the anterior approach, who do receive special care if obese. In our study, 64% of patients who underwent the anterior approach with metabolic syndrome were also obese. If patients with metabolic syndrome who were also obese received prophylactic wound care, the risk for wound complication conferred by their metabolic syndrome would be reduced by our management protocols. This is further supported by the observation that the wound complication prevalence over 1-year follow-up in our study (all approaches: 3%, anterior approach: 3.9%) is lower than has been reported in the literature. Wound complication prevalence has been reported at 5.7%-11.5%, with follow-up ranging from 30 days to 3 months [10,30,35]. Additional studies would be needed to determine whether the associations, or lack thereof, identified in this study apply at institutions where obese patients undergoing the anterior approach do not receive additional measures to prevent wound complications. From a clinical perspective, however, these findings would suggest that any increased risk associated with the anterior approach in obese patients previously reported in the literature can be mitigated by adopting the precautions taken at our institution.

This study has several limitations. First, this study was performed at a single institution, which may limit the generalizability of the findings to other populations. A case in point is our aforementioned proactive approach to limit wound complications in patients who underwent the anterior approach. Cross-institutional studies are needed to determine whether the associations we identified are consistent across institutions and other patient populations. We note, however, that the study was performed using only structured data and the analysis could easily be replicated at any institution with structured data of this nature in their own repository. Second, this was a retrospective chart review, which is limited to existing documented information. For example, because waist circumference, which is a core metabolic syndrome diagnostic criterion, is not a part of the standard institutional documentation, and not all laboratory values were available for all patients, our incidence of 11.9% likely underestimates the prevalence of metabolic syndrome among our population; in comparison, the U.S. adult population has an estimated metabolic syndrome prevalence of 34.2% between 2007 and 2012. Although the Pacific region has a lower reported prevalence of metabolic syndrome than the national population (29% [36]), the disease prevalence in this study remains considerably lower. Third, our sample size may have been too small to detect subtle differences. This lack of statistical power may explain why there was no significant association between obesity and secondary outcomes such as venous thromboembolism [30], which has previously been reported to be associated with obesity. Fourth, there may be some subtle differences in patient selection or patient treatment depending on the surgical approach, which could lead to misclassification and attenuate the magnitude of associations. For example, there was a higher prevalence of obesity among patients who underwent anterior vs posterior approach. Importantly, however, this would not be expected to impact the association between obesity and wound complications within each subgroup. Finally, we recognize that there are multiple definitions of metabolic syndrome and we evaluated only one. We selected the NCEP-ATPIII criteria because they are the most applicable for use in the clinical/preoperative setting and do not make assumptions about which components of metabolic syndrome are more essential. All of the remaining commonly used criteria make assumptions about the underlying etiology of metabolic syndrome, requiring the fulfillment of a core criterion (insulin resistance in the World Health Organization (WHO) and European Group for the Study of Insulin Resistance criteria, central obesity in the International Diabetes Federation criteria), and involve additional measurements that would be cumbersome to the workflow of the surgeon (fasting plasma insulin, glucose tolerance, euglycemic clamp studies, waist circumference) [27]. Perhaps future studies could be performed in an experimental setting to determine whether these definitions of metabolic syndrome are associated with the wound complication risk, although any additional findings would not be expected to negate the clinically meaningful associations found in the present study.

The major strength of this study was the separation of the metabolic from the BMI-related effects of adiposity by evaluating metabolic syndrome independently of the BMI. Previous studies have primarily considered an elevated BMI as the measure of obesity [6,9,10,31]. As the present study demonstrates, the BMI and metabolic dysregulation do not always co-occur and may have different effects on outcomes such as wound complications. This may explain why previous studies of obesity and wound complication have yielded conflicting results.

Conclusions

In summary, among patients undergoing THA by an arthroplasty-trained surgeon at a single institution, metabolic syndrome, but not an elevated BMI, was independently associated with the risk of wound complications in the 1-year period after

THA. This could alter clinical management as our modified definition of metabolic syndrome represents a distinct risk factor that can be discerned separately from the BMI based on clinical information that is already routinely obtained as part of the preoperative evaluation. Therefore, future studies are needed to determine whether individuals with metabolic syndrome would benefit from specific protocols to minimize their risk of wound complications after THA.

Conflict of interest

Acknowledgments

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