Metabolic syndrome in the setting of obesity: impact on in-hospital complications and outcomes after total knee and hip arthroplasty

From Oakland University William Beaumont School of Medicine, Rochester, Michigan, USA

Correspondence should be sent to A. K. Zalikha
akzalikha@gmail.com

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A. K. Zalikha,[1] M. A-A. Waheed,[1] C. Twal,[2] J. Keeley,[2] M. M. El-Othmani,[3] I. Hajj Hussein[2]

[1]Department of Orthopaedic Surgery, Detroit Medical Center/Wayne State University, Detroit, Michigan, USA
[2]Department of Foundational Medical Studies, Oakland University William Beaumont School of Medicine, Rochester, Michigan, USA
[3]Department of Orthopaedic Surgery, Warren Alpert School of Medicine, Brown University, Providence, Rhode Island, USA

Aims

This study aims to evaluate the impact of metabolic syndrome in the setting of obesity on in-hospital outcomes and resource use after total joint replacement (TJR).

Methods

A retrospective analysis was conducted using the National Inpatient Sample from 2006 to the third quarter of 2015. Discharges representing patients aged 40 years and older with obesity (BMI > 30 kg/m^2) who underwent primary TJR were included. Patients were stratified into two groups with and without metabolic syndrome. The inverse probability of treatment weighting (IPTW) method was used to balance covariates.

Results

The obese cohort with metabolic syndrome was significantly older, more likely to be female, had higher rates of Medicare insurance, and more likely to be non-Hispanic Black than the obese cohort without metabolic syndrome. In the unweighted analysis, patients with obesity and metabolic syndrome were more likely to experience cardiac, gastrointestinal, genitourinary, and postoperative anemia complications, had a longer length of stay, and were less likely to be discharged home compared to obese patients without metabolic syndrome. After adjusting for covariates using IPTW, patients with obesity and metabolic syndrome were more likely to experience postoperative anemia complications only and had lower rates of home discharge, but there were no significant differences in any other complication variables or length of stay.

Conclusion

Given the variability of metabolic health in obesity, the development of tailored perioperative protocols and recommendations acknowledging this variability in metabolic health in obese patients would ultimately potentially benefit patients and improve outcomes of TJR.

Take home message

- This study demonstrated that metabolic syndrome in the context of obesity is associated with an increased risk of complications in the inpatient postoperative period, longer length of stay, and lower rates of home compared to rehabilitation discharge.
- Perioperative optimization and appropriate counseling are recommended in these patients.

Introduction

Total joint replacement (TJR) of the hip and knee are effective procedures that help relieve symptoms, improve function,

and restore quality of life in patients with severe osteoarthritis, and are among the most frequently performed procedures in the USA.[1,2] As the life expectancy and functional demand of the elderly population continues to increase, so too is the demand for these procedures expected to increase.[3] Recent studies suggest that by 2030, the incidence of primary total hip arthroplasty (THA) and primary total knee arthroplasty (TKA) is projected to increase at a 71% and 85% growth rate, respectively.[4] Considering the already well-established burden that degenerative joint disease has placed on the US healthcare system, coupled with the recent transition to value-based care delivery models, research has now shifted towards focusing on risk stratification and understanding various modifiable and nonmodifiable risk factors in patients to improve overall TJR outcomes.[5]

Obesity and metabolic syndrome have been previously examined as independent risk factors for adverse outcomes following TJR. Metabolic syndrome is a cluster of interrelated metabolic dysregulations including obesity, insulin resistance, high blood pressure, and abnormal lipid levels that increase an individual's risk for developing cardiovascular disease and type 2 diabetes.[6,7] The prevalence of metabolic syndrome is increasing globally and has become a major public health concern. There is a growing body of evidence suggesting that metabolic syndrome is associated with adverse outcomes in TJR, including an increased risk of perioperative complications, prolonged hospital stays, and a higher rates of revision surgery.[8-11] Obesity has historically been associated with increased risk for TJR complications, though recent studies suggest that the role of obesity in TJR outcomes may not be as linear as once thought.[12-17] Although several studies have assessed the independent impact of obesity or metabolic syndrome on TJR outcomes, there is sparse literature that highlights the impact of metabolic syndrome on outcomes in the setting of obesity.

Therefore, the purpose of this study is to evaluate the impact of metabolic syndrome in obese patients on immediate in-hospital postoperative outcomes and complications after TJR. We hypothesize that obese patients with metabolic syndrome have higher rates of worse clinical outcomes compared to obese patients without metabolic syndrome.

Methods

A retrospective analysis was conducted using hospital discharge data from 2006 to the third quarter of 2015 from the National Inpatient Sample (NIS), which is part of the Hospital Cost and Use Project.[18] The NIS is the largest inpatient database in the USA, covering all payer types, and is based on a 20% stratified sample of discharges from USA hospitals. The sample is weighted to provide accurate national estimates and includes patient demographics, perioperative outcomes, and charges. The International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) was used by the NIS as the coding system for procedures and diagnoses during our study period.[18] To eliminate any discrepancies in diagnosis coding, patients from the fourth quarter of 2015 were excluded, as the NIS switched to ICD-10 codes during that period. This study was granted exempt status by our Institutional Review Board.

Patients who underwent a primary THA or primary TKA and were aged at least 40 years were included in our study. We identified these patients using ICD-9 codes 81.51 (THA) and 81.54 (TKA). We accounted for discharge weights, clusters, and strata as recommended by the Agency for Healthcare Research and Quality. Once the TJR cohorts were identified, patients were further stratified into two groups: obese patients without a concomitant diagnosis of metabolic syndrome (ICD-9 codes: V85.30-V85.45, 278.0, 278.01) and obese patients with a concomitant diagnosis of metabolic syndrome. The diagnosis of interest, metabolic syndrome, was defined based on ICD-9 code 277.7 or having at least three out of five components of metabolic syndrome: high blood pressure (ICD-9 codes: 401–405), obesity/BMI ≥ 30/kgm^2 (ICD-9 codes: V85.3-V85.45, 278.0, 278.01), altered fasting glucose (ICD-9 codes: 250.00, 250.02, 250.10, 250.12, 250.20, 250.22, 250.30, 250.32, 250.40, 250.42, 250.50, 250.52, 250.60, 250.62, 250.70, 250.72, 250.80, 250.82, 250.90, 250.92), low HDL cholesterol (ICD-9 codes: 272.5–272.6), and high triglycerides (ICD-9 codes: 272.1–272.4). The use of these codes aims to approximate the disease-defining entities of metabolic syndrome and has been used in numerous previous studies.[19–21]

This study used the inverse probability of treatment weighting (IPTW) method to balance covariates in complex data and minimize the impact of confounding bias. This statistical approach was performed using the Dugoff et al method,[22] which considered patient demographics and comorbidities using a modified Elixhauser Comorbidity Index (ECI).[23] The ECI takes into account multiple comorbidities and has been found to be a useful tool in large database research for evaluating patient comorbidities and controlling for the potential impact of pre-existing diseases on outcomes. The index was modified to exclude comorbidity variables that are included in the diagnosis of the cohorts of interest in this study, including hypertension, diabetes, and obesity. The use of IPTW incorporating the aforementioned variables was chosen to control for confounding effects. This method is comparable to standard matching techniques, but is more appropriate for this study design, as matching would be challenging with multiple cohorts and would result in significant data loss. The model effectively balances the impact of comorbidities without sacrificing the large number of patients in the study, which essentially aims to produce conclusions that are representative of the entire population.

Postoperative complications that were analyzed included cardiac, peripheral vascular disease (PVD), respiratory, gastrointestinal (GI), genitourinary (GU), haematoma/seroma, wound dehiscence, postoperative infection, deep vein thrombosis, pulmonary embolism, and postoperative anemia complications. Patient demographics, length of stay (LOS), and home versus rehabilitation discharge were compared using weighted cohorts.

Statistical analysis

The analysis of continuous data was conducted using independent-samples t-tests and categorical data was analyzed via Rao-Scott chi-squared tests when applicable. The statistical significance of the data was set at a p-value < 0.05 and all tests were two-sided. All statistical analyses accounted for the complex survey design of the NIS and were carried out using SAS v. 9.4 for Windows (SAS Institute, USA).

Table I. Demographics and hospital descriptive data of the entire study period of obese patients with and without metabolic syndrome.

Variable	Obese with MetS	Obese without MetS	p-value
Mean age, yrs (SD)	64.8 (0.03)	61.5 (0.03)	< 0.0001*
Sex, n (%)			< 0.0001†
Male	282,625 (37.19)	311,286 (31.60)	
Female	477,267 (62.81)	673,672 (68.38)	
Hospital region, n (%)			< 0.0001†
Northeast	113,587 (14.95)	153,884 (15.62)	
Midwest	218,841 (28.80)	244,450 (24.81)	
South	238,161 (31.34)	280,721 (28.50)	
West	121,698 (16.01)	179,382 (18.21)	
Unknown	67,615 (8.90)	126,705 (12.86)	
Pay, n (%)			< 0.0001†
Medicare	404,093 (53.18)	390,168 (39.61)	
Medicaid	27,922 (3.67)	44,856 (4.55)	
Private insurance	300,776 (39.58)	504,725 (51.23)	
Other	25,564 (3.37)	43,326 (4.40)	
Race, n (%)			< 0.0001†
White	529,960 (69.74)	696,533 (70.70)	
Black	72,690 (9.57)	86,098 (8.74)	
Hispanic	37,123 (4.89)	43,016 (4.37)	
Asian/Pacific Islander	5,693 (0.75)	4,431 (0.45)	
Native American	3,214 (0.42)	3,685 (0.37)	
Other	111,221(14.64)	151,378 (15.37)	
Urban/rural, n (%)			0.1951†
Rural	72,766 (9.58)	88,227 (8.96)	
Urban	616,819 (81.17)	767,209 (77.88)	
Unknown	70,317 (9.25)	129,705 (13.17)	

*Independent-samples.
†Chi-squared test.
MetS, metabolic syndrome.

Table II. Presence of Elixhauser comorbidities in obese patients with and without metabolic syndrome.

Variable	Obese with MetS (n = 759,901), %	Obese without MetS (n = 985,141), %	p-value*
AIDS	0.01	0.03	0.0001
Alcohol abuse	0.97	1.00	0.2953
Deficiency anaemias	14.80	11.96	< 0.0001
Rheumatoid arthritis/collagen vascular diseases	3.34	3.88	< 0.0001
Chronic blood loss anemia	1.69	1.50	0.0001
Congestive heart failure	4.64	2.31	< .0001
Chronic pulmonary disease	19.95	18.23	< 0.0001
Coagulopathy	2.34	1.71	< 0.0001
Depression	17.13	16.05	< 0.0001
Diabetes, uncomplicated	53.67	6.61	< 0.0001
Diabetes with chronic complications	6.14	0.60	< 0.0001
Drug abuse	0.59	0.77	< 0.0001
Hypertension	96.94	58.27	< 0.0001
Hypothyroidism	17.45	15.86	< 0.0001
Liver disease	1.45	1.15	< 0.0001
Lymphoma	0.20	0.22	0.1638
Electrolyte disorders	11.23	7.84	< 0.0001
Metastatic cancer	0.07	0.09%	0.1476
Other neruological disorders	4.0	3.68	< 0.0001
Paralysis	0.27	0.20	< 0.0001
Peripheral vascular disorders	3.24	1.35	< .0001
Psychoses	2.85	2.65	0.0007
Pulmonary circulation disorder	1.58	1.14	< 0.0001
Renal failure	8.19	2.83	< 0.0001
Solid tumour without metastasis	0.41	0.32	< 0.0001
Peptic ulcer disease	0.02	0.01	0.3677
Valvular disease	3.93	2.76	< 0.0001

*Chi-squared test.
MetS, metabolic syndrome.

Results

Demographics and hospital data

In our study period, an estimated total of 5,902,057 TKA and 2,838,742 THA discharges were reviewed for inclusion criteria in our database. For all TJRs (n = 8,740,799), 1,745,042 (19.96%) had a comorbid diagnosis of obesity and were eligible for inclusion. Of the discharges with obesity, 757,901 (43.43%) had a concomitant diagnosis of metabolic syndrome, while 985,141 (56.45%) did not have a concomitant diagnosis of metabolic syndrome.

During the study period, there were statistically significant associations in multiple demographic and hospital factors between discharges with and without metabolic syndrome. The metabolic syndrome cohort was on average significantly older, more likely to be female, had higher rates of Medicare as primary payor, and more likely to be non-Hispanic Black and less likely to be non-Hispanic White in comparison to the cohort without metabolic syndrome. Table I provides a complete description of these demographic and hospital factors.

Elixhauser Comorbidities Index

Patients with metabolic syndrome were significantly more likely to have 20 of the 27 analyzed Elixhauser comorbidities, while those without metabolic syndrome had significantly higher rates of three comorbidities. Table II provides a complete analysis of Elixhauser comorbidities between the two groups.

Inpatient outcomes

There were statistically significant association between metabolic syndrome and higher likelihood to experience cardiac (0.72% vs 0.55%, p < 0.0001), gastrointestinal (0.26% vs 0.22%, p = 0.0163) genitourinary (0.57% vs 0.41%, p < 0.0001) complications, and postoperative anaemia (24.67% vs 21.38%, p < 0.0001, all chi-squared test) compared with obese patients without metabolic syndrome. Patients with metabolic syndrome had a statistically significantly longer LOS

Table III. Unweighted outcomes in obese patients with and without metabolic syndrome.

Complication or other outcome	Obese with MetS, %	Obese without MetS, %	p-value
Length of stay, days	3.3	3.2	< 0.0001*
Discharge home	61.03	68.35	< 0.0001†
Central nervous system	0.07	0.08	0.8346†
Cardiac	0.72	0.55	< 0.0001†
Deep vein thrombosis	0.34	0.34	0.9913†
Gastrointestinal	0.26	0.22	0.0163†
Genitourinary	0.57	0.41	< 0.0001†
Haematoma/seroma	0.55	0.54	0.6762†
Postoperative infection	0.15	0.15	0.9265†
Pulmonary embolism	0.4	0.45	0.3785†
Postoperative anaemia	24.67	21.38	< 0.0001†
Peripheral vascular disease	0.10	0.11	0.6005†
Respiratory	0.13	0.14	0.6673†
Wound dehiscence	0.11	0.10%	0.3623

*Independent-samples *t*-test.
†Chi-squared test.
MetS, metabolic syndrome.

Table IV. Adjusted inverse probability of treatment weighting outcomes in obese patients with and without metabolic syndrome.

Complication or other outcome	Obese with Mets, %	Obese without MetS, %	p-value
Length of stay, days	3.3	3.2	< 0.0001*
Discharge home	63.53	65.81	< 0.0001†
Central nervous system	0.07	0.09	0.1000†
Cardiac	0.65	0.64	0.6866†
Deep vein thrombosis	0.32	0.36	0.0748†
Gastrointestinal	0.24	0.25	0.3441†
Genitourinary	0.51	0.49	0.5156†
Haematoma/seroma	0.53	0.57	0.1117†
Postoperative Infection	0.15	0.17	0.1176†
Pulmonary embolism	0.46	0.49	0.1177†
Postoperative anaemia	24.16	21.86	< 0.0001†
Peripheral vascular disease	0.10	0.12	0.0586†
Respiratory	0.13	0.15	0.1959†
Wound dehiscence	0.11	0.11	0.9873†

*Independent-samples *t*-test.
†Chi-squared test.
MetS, metabolic syndrome.

(3.3 vs 3.2 days, p < 0.0001, independent-samples *t*-test) and were significantly less likely to be discharged home (61.03% vs 68.35%, p < 0.0001, chi-squared test) compared to those without metabolic syndrome. Table III details all outcomes in the unadjusted analysis.

Following the IPTW analysis, metabolic syndrome patients were noted to have a higher likelihood to experience postoperative anemia (24.16% vs 21.86%, p < 0.0001, chi-squared test), but there were no statistically significant differences in the other complications. In the IPTW analysis, obese patients with metabolic syndrome were still significantly less likely to be discharged home compared to obese patients without metabolic syndrome (63.53% vs 65.81%, p < 0.0001, chi-squared test) and still had significantly longer lengths of stay (3.3 vs 3.2, p < 0.0001, independent-samples *t*-test). Table IV details all outcomes in the IPTW comparative analysis.

Discussion

Conflicting findings exist in recent literature regarding the impact of obesity on outcomes after TJR. Some studies reveal a J-shaped, non-linear curve, suggesting a normal or even protective effect of moderate obesity on postoperative arthroplasty outcomes, while higher BMIs correlate with worse outcomes.[12,13,24] In contrast, some earlier studies demonstrated worse outcomes for all obese patients after TJR.[25,26] Obesity impacts metabolic, bone, and overall health, although this impact is highly variable and complex.[27–30] Identifying high-risk subgroups within the obese population could help better predict risk and develop targeted, patient-specific perioperative protocols to improve postoperative outcomes. As the presence of metabolic syndrome can help differentiate between the metabolically healthy and unhealthy obese patient, this study aimed to compare outcomes between these two groups.[31] Our unadjusted analysis indicates significantly higher rates of complications, longer LOS, and lower rates of home discharge for obese patients with metabolic syndrome compared to those without metabolic syndrome.

However, when IPTW, a method that helps reduce bias by controlling for confounding variables, was applied to control for demographic and comorbidities constituting the modified Elixhauser index (excluding metabolic syndrome-defining comorbidities), several of these complication differences were no longer present. These findings indicate that metabolic syndrome, reflecting an overall poorer metabolic and general health status, is correlated with worse outcomes in obese patients. However, controlling for other comorbidities, which often occur in conjunction with metabolic syndrome, in our IPTW analysis allowed for discerning how other health factors and conditions may be contributing to the observed increase in risk, rather than attributing it solely and independently to metabolic syndrome. Hence, our IPTW analysis suggests that metabolic syndrome may be a signal for poorer overall health, encompassing a range of other conditions that together lead to worse outcomes. The independent contribution of metabolic syndrome itself, however, may not be as relevant in risk prediction and stratification compared to other comorbidities and underlying health factors.

Recent literature has demonstrated an increased risk of complications after TJR in patients with metabolic syndrome.[9-11] These authors often highlight the increased value of metabolic syndrome relative to obesity in assessing for risk after TJR. Such recommendations are encouraging, given that the general medical literature has highlighted the importance of differentiating metabolically healthy versus unhealthy obese patients.[32,33] This general medical literature emphasizes the various subgroups within the vast obese population

and the importance of identifying these distinct cohorts to better predict individual patient health and risk. In contrast, arthroplasty literature has often adopted a relatively simplistic and perhaps unsophisticated approach, often grouping all obese patients, or all obese patients above a certain BMI, into a single cohort and generating recommendations based on this large group that is potentially diverse in metabolic and overall health. This oversimplification neglects the complex interplay of comorbidities and the variability of the metabolic and overall health of these patients. To the credit of the arthroplasty literature, recent studies have distinguished between moderately and morbidly obese patients, recognizing the health diversity within obesity.[17,24] While these findings are encouraging and help to categorize different obese cohorts, one might speculate that morbid obesity may merely signal worse metabolic and overall health status compared to moderate obesity. While this study specifically used comorbid metabolic syndrome to stratify obese patients, combining methods to stratify patients based on severity of obesity, and accounting for various other comorbidities and health factors, may offer a more nuanced understanding of patient-specific metabolic and overall health, thereby enhancing risk classification. Future arthroplasty research should better differentiate metabolically healthy and unhealthy obese populations, with evidence-based recommendations tailored to these distinct cohorts.

The American Association of Hip and Knee Surgeons and the American Academy of Orthopaedic Surgeons have both suggested higher rates of complications in morbidly obese patients, with the former recommending in 2013 to delay surgery for patients with BMI > 40 kg/m^2.[14,34] These recommendations were based on evidence that did not consistently demonstrate worse outcomes and postoperative functional scores in obese (BMI 30 kg/m^2 to 39.9 kg/m^2) versus non-obese cohorts. Comparatively, formal guidelines for patients with metabolic syndrome undergoing TJR are lacking. Still, a growing evidence base supports the need for perioperative medical and functional optimization as reasonable goals with limited harm in these patients. Further research should evaluate the benefits and potential harms of such interventions and delaying surgery in patients with metabolic syndrome or other signals of overall poorer health status. Moreover, given the variability in metabolic health in those with obesity, future literature should investigate the outcomes and impact of interventions in obese patients with and without metabolic syndrome, ultimately leading to patient-specific risk prediction and targeted perioperative decision-making and optimization protocols.

Several limitations, many of which are inherent to large database studies, are present in this study. First, the NIS database only includes information on inpatient hospital stays, precluding the reporting of long-term outcomes, including revisions and readmissions. Still, the inpatient period is critical for perioperative care and planning, and analyzing this period provides useful and practical data. Further, national databases like the NIS may be incomplete or contain errors, potentially affecting the veracity of results and interpretations. However, Bozic et al[35] found that comorbidity and complication data in administrative databases correlate reasonably well with the clinical record and have a high degree of specificity. Finally, this study grouped all obese patients in a single cohort, limiting the granularity of the analysis. It would be valuable for continued work to analyze the impact of metabolic syndrome in obese patients with various BMIs.

Despite these inherent limitations, this study had numerous strengths. This study represents a large national analysis of an important patient population, providing valuable insights into the impact of metabolic syndrome in the setting of obesity on postoperative outcomes. The use of the NIS database allowed for a comprehensive analysis of a large and diverse population, increasing the generalizability of the findings. This study was also strengthened by the IPTW methodology, which allowed for a unique adjusted analysis by controlling important demographic and comorbidity factors, thus limiting the impact of confounding bias without loss of the number of included discharges.

In conclusion, this study demonstrated that obese patients with metabolic syndrome have an increased risk of complications in the inpatient postoperative period, longer LOS, and lower rates of home compared to rehabilitation discharge. However, the significant differences in several complication outcomes did not persist in the adjusted analysis, suggesting that the increased risk of these complications may be less likely attributed to the disease-defining comorbidities and more likely to the worse overall general health status of this population. Given the variability of metabolic health in obesity, future studies should stratify the various subsets of obese patients and investigate this metabolic health diversity. These findings bring attention to the importance of considering metabolic and overall health status in the context of obesity when examining TJR outcomes, emphasizing the need for a multidisciplinary and holistic approach to optimize patient care and improve TJR outcomes. The development of tailored perioperative optimization protocols for these various populations would benefit these patients, with the goal of achieving improved postoperative outcomes and a more personalized and effective approach to care.

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Author information

A. K. Zalikha, MD, Physician
M. A-A. Waheed, MD, Resident Physician
Department of Orthopaedic Surgery, Detroit Medical Center/ Wayne State University, Detroit, Michigan, USA.

C. Twal, MD, Medical Student
J. Keeley, MS, Statistician
I. Hajj Hussein, PhD, Associate Professor
Department of Foundational Medical Studies, Oakland University William Beaumont School of Medicine, Rochester, Michigan, USA.

M. M. El-Othmani, MD, Assistant Professor, Department of Orthopaedic Surgery, Warren Alpert School of Medicine, Brown University, Providence, Rhode Island, USA.

Author contributions

A. K. Zalikha: Conceptualization, Formal analysis, Writing – review & editing, Writing – original draft, Methodology.
M. A-A. Waheed: Conceptualization, Formal analysis, Writing – review & editing, Writing – original draft.
C. Twal: Conceptualization, Formal analysis, Writing – review & editing, Writing – original draft.
J. Keeley: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing, Methodology.
M. M. El-Othmani: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing, Methodology.
I. Hajj Hussein: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing, Methodology.

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