Clinical/Basic Science Research Article

ORTHOPAEDIC TRAUMA ASSOCIATION
OTA INTERNATIONAL
THE OPEN ACCESS JOURNAL OF ORTHOPAEDIC TRAUMA

OPEN

A component-based analysis of metabolic syndrome's impact on 30-day outcomes after hip fracture: reduced mortality in obese patients

Aaron Singh, BA*, Travis Kotzur, BS, Irene Vivancos-Koopman, BA, Chimobi Emukah, MD, Christina Brady, MD, Case Martin, MD

Abstract

Introduction: Hip fractures are a common injury associated with significant morbidity and mortality. In the United States, there has been a rapid increase in the prevalence of metabolic syndrome (MetS), a condition comprised several common comorbidities, including obesity, diabetes mellitus, and hypertension, that may worsen perioperative outcomes. This article assesses the impact of MetS and its components on outcomes after hip fracture surgery.

Methods: Patients who underwent nonelective operative treatment for traumatic hip fractures were identified in the 2015–2020 American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database. Baseline characteristics between groups were compared, and significant differences were included as covariates. Multivariate regression was performed to assess the impact of characteristics of interest on postoperative outcomes. Patients with MetS, or a single one of its constitutive components—hypertension, diabetes, and obesity—were compared with metabolically healthy cohorts.

Results: In total 95,338 patients were included. Patients with MetS had increased complications (OR 1.509; $P < 0.001$), but reduced mortality (OR 0.71; $P < 0.001$). Obesity alone was also associated with increased complications (OR 1.14; $P < 0.001$) and reduced mortality (OR 0.736; $P < 0.001$). Both hypertension and diabetes alone increased complications ($P < 0.001$) but had no impact on mortality. Patients with MetS did, however, have greater odds of adverse discharge (OR 1.516; $P < 0.001$), extended hospital stays (OR 1.18; $P < 0.001$), and reoperation (OR 1.297; $P = 0.003$), but no significant difference in readmission rate.

Conclusion: Patients with MetS had increased complications but decreased mortality. Our component-based analysis showed had obesity had a similar effect: increased complications but lower mortality. These results may help surgeons preoperatively counsel patients with hip fracture about their postoperative risks.

Keywords: hip fractures, metabolic syndrome, risk stratification, geriatric trauma, obesity

1. Introduction

Hip fractures are common injuries, with the annual incidence expected to rise to over 500,000 by 2040.[1] Most of these result from low-energy trauma, such as a fall, in the 65 years and older patient population.[2,3] Although common, these are serious injuries, resulting in significant disability, morbidity, and mortality.[4–8] In fact, estimates of 1-year mortality range from 22% to approximately 33% in the first year after a hip fracture, representing a 3–4 times greater risk of death relative to the general population.[8–11] Owing to this risk, proper management of these injuries is imperative.

Another concern is the rising prevalence of metabolic syndrome (MetS), attributable to increasing rates of obesity.[12–14] MetS is a constellation of symptoms generally including some combination of obesity, high fasting glucose (diabetes mellitus), dyslipidemia, or hypertension.[15–17] Both obesity and MetS are linked to increased risk for multiple diseases, particularly serious cardiovascular events such as myocardial infarction and stroke, and all-cause mortality.[18–22] Although the impact of MetS on the cardiovascular system is relatively well understood, its relationship to the musculoskeletal system is less well characterized.

Several studies found MetS to be associated with lower bone mineral density[23–26]; however, others found an overall lower fracture risk in these patients.[27–29] These inconsistencies may be due to the multifactorial nature of MetS—it is a composite of several pathologies—or disparate effects on differing anatomical structures (eg, obesity may affect weight-bearing joints differently than non–weight-bearing ones).[29,30] These mixed findings suggest that research into MetS with respect to musculoskeletal and orthopaedic outcomes is warranted. The purpose of this study was to assess the impact of metabolic syndrome, as well as its individual components (obesity, hypertension, and diabetes mellitus), on outcomes after hip fracture surgery. We hypothesize that patients with MetS, and those with components of MetS, will have worse outcomes after operative management of hip fractures.

The authors do not declare any conflict of interest regarding the publication of this manuscript.

Department of Orthopaedics, UT Health San Antonio, San Antonio, TX

** Corresponding author. Address: Department of Orthopaedics, UT Health San Antonio, 7703 Floyd Curl Dr, MC-7774, San Antonio, TX 78229-3900. E-mail address: singha6@livemail.uthscsa.edu (A. Singh).*

Source of funding: Nil.

IRB Protocol: 20220640NHR; no IRB approval was required.

OTAI (2024) e301

http://dx.doi.org/10.1097/OI9.0000000000000301

2. Methods

2.1. Data Source and Collection

This study was a retrospective review using the American College of Science–National Surgical Qualitative Improvement Program (ACS-NSQIP), years 2015–2020. The ACS-NSQIP is a validated national data set that contains preoperative and 30-day postoperative outcomes for surgical procedures.[31] We queried this database for all adult patients (18 or older) undergoing operative management of traumatic hip fractures. Patients undergoing the following procedures, identified through Current Procedural Terminology (CPT) codes, were selected for inclusion: total hip arthroplasty (CPT 27130), hip hemiarthroplasty (CPT 27125), and open reduction internal fixation (CPT 27236, 27244, 27245). To better restrict the study to isolated traumatic hip fractures, patients with concurrent procedures, other planned procedures, and those undergoing elective procedures were excluded. Patients with periprosthetic fractures or patients undergoing surgery for degenerative disease or hip deformities were also excluded through International Classification of Diseases-10 codes M97 and M16, respectively. Patients with incomplete data were excluded as were underweight patients (body mass index [BMI] below 18.5).

2.2. Outcome Grouping

Patient characteristics were collected from the ACS-NSQIP and include demographics, medical comorbidities, preoperative data, intraoperative data, and postoperative data. Postoperative data included 30-day complications, life-threatening complications, hospital length of stay, readmission, any unplanned reoperation with 30 days, and adverse discharge disposition, defined as a nonhome discharge. Complications were grouped by organ system and were defined as the following occurrences within 30 days of surgery: cardiac complication is defined as any occurrence of cardiac arrest requiring cardiopulmonary resuscitation (CPR) or myocardial infarction; pulmonary complication is defined as any occurrence of pneumonia, pulmonary embolism, unplanned intubation, or being on a ventilator for more than 48 hours; renal complication is defined as occurrence of acute renal failure or progressive renal insufficiency; hematological complication is defined as occurrence of DVT or bleeding requiring a transfusion; and wound complication is defined as the occurrence of a superficial, deep, or organ level surgical site infection or wound dehiscence. Clavien–Dindo IV includes life-threatening complications and consists of the following: cardiac arrest requiring CPR, myocardial infarction, septic shock, pulmonary embolism, acute renal failure, or cerebral vascular accident/stroke with neurological defect within 30 days of surgery. Clavien–Dindo IV complications enable assessment of the most severe complications, regardless of type or organ system.

2.3. Statistical Analysis of MetS

A modified, but previously used, definition of MetS was used to query the ACS-NSQIP. This modified criterion defines MetS as having the 3 following comorbidities, concomitantly: 1) BMI > 30, 2) diabetes mellitus, and 3) hypertension requiring medication. This modified MetS has been widely used in related literature, both in orthopaedics and otherwise.[32–37]

To assess each component of MetS individually, patients with a single component (eg, obesity) were compared with a metabolically healthy cohort without the characteristic of interest (eg, nonobese patients, who, by definition, do not have MetS). For patients with MetS, the comparison group consisted of patients without MetS or obesity. This same group was compared with an obese cohort (patients with a BMI > 30). A cohort consisting of patients with hypertension were compared to patients without hypertension. In a similar fashion, an additional cohort of patients with diabetes were compared to a control group of patients without diabetes. This design allowed us to isolate MetS and compare each of its individual components to a metabolically healthy control group. We further stratified obese patients into obesity class. Class I obesity was defined as BMI between 30 and 35, class II included patients with a BMI between 35 and 40, while class III obesity comprised patients with a BMI greater than 40.

The Pearson χ^2 test was performed for demographics, comorbidities, preoperative, and intraoperative data to compare baseline differences between patients with MetS, metabolically healthy patients, and patients with a single comorbidity. All categorical variables are reported as N samples with column percentages. All linear variables are reported as means with standard deviations. All covariates that had a P value of $P < 0.1$ were included as an independent variable for multivariate regression. Outcomes required a preadjusted P value of $P < 0.05$ to be considered for multivariate logistic regression. Variables with a P value <0.05 after multivariate regression were considered significant, and the results were reported as adjusted odds ratio (OR) and 95% confidence interval (CI).

Finally, a Kaplan–Meier survival analysis was performed to compare in-hospital mortality between groups. Patient cohorts compared include those with MetS, obesity alone, hypertension alone, diabetes alone, and, lastly, a health control group. Survival was graphed out to 3 standard deviations above the mean length of stay. Survivorship was extrapolated based on the length of stay and documentation of an in-hospital death. All statistical analysis was performed using R Foundation for Statistical Computing software version 4.20 "https://www.r-project.org."

3. Results

3.1. Demographics

A total of 95,338 patients were included in our study. In total, 4935 (5.18%) met criteria for MetS, whereas the remaining 90,403 (94.82%) did not. The MetS cohort was significantly younger ($P < 0.001$) with a mean age of 75.003 (9.636) compared with 79.499 (10.765) for those without MetS. The mean BMIs were 35.096 (5.202) and 25.247 (4.768) for the MetS and non-MetS groups, respectively. Although most patients were women (67.38%), men were overrepresented in the MetS population, composing 35.68% of that population, but only 32.46% in the metabolically healthy group. We had similar findings with respect to minority groups, Black (4.74% vs. 3.46%), and Hispanic (7.11 vs. 4.77%) population contributing disproportionately more to the MetS than non-MetS groups. Full demographics are presented in Table 1.

3.2. Postoperative outcomes

Patients with MetS were 1.509 times more likely to have any complication ($P < 0.001$). Specifically, they were significantly more likely to have cardiac (OR 1.26; $P = 0.007$), wound (OR 1.909; $P < 0.001$), and renal complications (OR 2.088; $P < 0.001$). These complications were more likely to be life threatening, with increased odds of Clavien–Dindo IV

TABLE 1.

Demographics and Covariates

Variable	MetS	No MetS	Total	P
Demographics				
Total number, N (%)	4935 (5.18)	90,403 (94.82)	95,338	
Age (y), mean (SD)	75.003 (9.636)	79.499 (10.765)	79.266 (10.756)	**<0.001**
Age category				**<0.001**
<55	98 (1.99)	2540 (2.81)	2638 (2.77)	
55–64	598 (12.12)	6597 (7.30)	7195 (7.55)	
65–79	2480 (50.25)	27,109 (29.99)	29,589 (31.04)	
≥80	1759 (35.64)	54,157 (59.91)	55,916 (58.65)	
Body mass index, mean (SD)	35.096 (5.202)	25.247 (4.768)	25.757 (5.265)	**<0.001**
BMI category				**<0.001**
<30	0 (0.0)	79,162 (87.57)	79,162 (83.03)	
30–34.99	3108 (62.98)	7999 (8.85)	11,107 (11.65)	
35–39.99	1188 (24.07)	2069 (2.29)	3257 (3.42)	
≥40	639 (12.95)	1173 (1.30)	1812 (1.90)	
Hispanic	351 (7.11)	4315 (4.77)	4666 (4.89)	**<0.001**
Race				**<0.001**
American Indian or Alaska Native	33 (0.67)	370 (0.41)	403 (0.42)	
Asian	55 (1.11)	2082 (2.30)	2137 (2.24)	
Black or African American	234 (4.74)	3125 (3.46)	3359 (3.52)	
Native Hawaiian or Pacific Islander	10 (0.20)	111 (0.12)	121 (0.13)	
Unknown/not reported	878 (17.79)	18,231 (20.17)	19,109 (20.04)	
White	3725 (75.48)	66,480 (73.54)	70,205 (73.64)	
Other	0 (0.0)	4 (0.00)	4 (0.00)	
Sex				**<0.001**
Female	3174 (64.32)	61,060 (67.54)	64,234 (67.38)	
Male	1761 (35.68)	29,343 (32.46)	31,104 (32.62)	
Comorbidity				
Ascites	26 (0.53)	237 (0.26)	263 (0.28)	**0.001**
Bleeding disorders	1124 (22.78)	14,321 (15.84)	15,445 (16.20)	**<0.001**
Preoperative dialysis	229 (4.64)	1663 (1.84)	1892 (1.98)	**<0.001**
Diabetes				**<0.001**
IDDM	2520 (51.06)	5687 (6.29)	8207 (8.61)	
NIDDM	2415 (48.94)	8386 (9.28)	10,801 (11.33)	
Disseminated cancer	74 (1.50)	1491 (1.65)	1565 (1.64)	0.454
Dyspnea				**<0.001**
At rest	92 (1.86)	851 (0.94)	943 (0.99)	
At moderate exertion	553 (11.21)	5880 (6.50)	6433 (6.75)	
Functional status before surgery				**<0.001**
Independent	3983 (80.71)	71,284 (78.85)	75,267 (78.95)	
Partially dependent	811 (16.43)	15,680 (17.34)	16,491 (17.30)	
Totally dependent	101 (2.05)	2713 (3.00)	2814 (2.95)	
Congestive heart failure in 30 d	372 (7.54)	3218 (3.56)	3590 (3.77)	**<0.001**
Prior to surgery				
History of severe COPD	672 (13.62)	9216 (10.19)	9888 (10.37)	**<0.001**
Hypertension requiring medication	4935 (100.00)	59,045 (65.31)	63,980 (67.11)	**<0.001**
Hypoalbuminemia	3043 (61.66)	55,393 (61.27)	58,436 (61.29)	0.596
History of systemic sepsis				**<0.001**
Sepsis	38 (0.77)	484 (0.54)	522 (0.55)	
Septic shock	9 (0.18)	47 (0.05)	56 (0.06)	
SIRS	681 (13.80)	10,546 (11.67)	11,227 (11.78)	
Acute renal failure	71 (1.44)	583 (0.64)	654 (0.69	**<0.001**
Smoker within past year	525 (10.64)	10,638 (11.77)	11,163 (11.71)	**0.017**
Chronic steroid use	310 (6.28)	4622 (5.11)	4932 (5.17)	**<0.001**
Transfusion within 72 h of surgery	217 (4.40)	3233 (3.58)	3450 (3.62)	**0.003**
Ventilator dependent	22 (0.45)	168 (0.19)	190 (0.20)	**<0.001**
Wound infection	256 (5.19)	2898 (3.21)	3154 (3.31)	**<0.001**
>10% weight loss in the past 6 mo	20 (0.41)	1305 (1.44)	1325 (1.39)	**<0.001**
Preoperative				
ASA class				**<0.001**
I	1 (0.02)	819 (0.91)	820 (0.86)	
II	343 (6.95)	16,539 (18.29)	16,882 (17.71)	
III	3338 (67.64)	56,419 (62.41)	59,757 (62.68)	
IV	1241 (25.15)	16,514 (18.27)	17,755 (18.62)	
V	12 (0.24)	112 (0.12)	124 (0.13)	

(*continued on next page*)

TABLE 1. (*continued*)

Variable	MetS	No MetS	Total	P
Time to operation				**<0.001**
>2 d	1303 (26.40)	19,788 (21.89)	21,091 (22.12)	
0–2 d	3632 (73.60)	70,615 (78.11)	74,247 (77.88)	
Transferred from				**<0.001**
Acute care hospital inpatient	320 (6.48)	4843 (5.36)	5163 (5.42)	
Home	3702 (75.02)	67,934 (75.15)	71,636 (75.14)	
Nursing home/chronic care	356 (7.21)	8690 (9.61)	9046 (9.49)	
Other/unknown	55 (1.11)	1065 (1.18)	1120 (1.17)	
Outside ED	502 (10.17)	7871 (8.71)	8373 (8.78)	
Operative				
Anesthesia type				
General	3935 (79.74)	65,661 (72.63)	69,596 (73.00)	**<0.001**
Other	Other	999 (20.24)	24,733 (27.36)	
Procedure				**<0.001**
HA	469 (9.50)	11,030 (12.20)	11,499 (12.06)	
ORIF	4197 (85.05)	74,323 (82.21)	78,520 (82.36)	
THA	269 (5.45)	5050 (5.59)	5319 (5.58)	

Boldface values indicate statistical significance ($P < 0.05$).

complications (OR 1.175; $P = 0.011$). With respect to hospital-related outcomes, they were 1.516 times more likely to have an adverse discharge disposition ($P < 0.001$), 1.18 times more likely to have an extended (greater than 5 days) length of hospital stay (LOS) ($P < 0.001$), and 1.297 times more likely to require reoperation ($P = 0.003$). Finally, and most significantly, MetS was associated with reduced mortality (OR 0.71; $P < 0.001$). Full results are presented in Figure 1. Raw totals and full postoperative outcome breakdowns for MetS and non-MetS patients are presented in Table 2.

Our findings were similar in obese patients. Obese patients were 1.14 times more likely to have any complication ($P < 0.001$). Specifically, they were more likely to have wound (OR 1.875; $P < 0.001$) and renal complications (OR 1.364; $P = 0.01$) but had reduced odds of hematological complications (OR 0.878; $P < 0.001$). Notably, we did not observe increased cardiac complications in this cohort. Obese patients did, however, have greater odds of reoperation (OR 1.258; $P < 0.001$) and extended LOS (OR 1.072; $P = 0.002$). In contrast to the MetS cohort, we found no significant change in the rate of Clavien–Dindo IV complications, but we did observe significantly reduced mortality in this population (OR 0.736; $P < 0.001$). Full results are presented in Figure 2.

Class I obesity was associated with 1.09 times more complications ($P = 0.008$), specifically renal (OR 1.45; $P = 0.007$) and wound complications (OR 1.628; $P < 0.001$). These patients were also more likely to have an adverse discharge (OR 1.15; $P < 0.001$) and have an extended LOS (OR 1.048; $P < 0.001$). However, they had significantly reduced mortality (OR 0.739; $P < 0.001$). Full results for class I obesity are presented in Figure 3.

Patients who were class II obese had greater odds of any complication (OR 1.141; $P = 0.03$). They had greatly increased odds of wound complications (OR 2.395; $P < 0.001$), but slightly reduced odds of hematological ones (OR 0.825; $P < 0.001$). They also had increased odds of an adverse discharge disposition (OR 1.249; $P < 0.001$) and reoperation (OR 1.559; $P < 0.001$), but reduced mortality (OR 0.739; $P = 0.019$). Full results for these patients are presented in Figure 4.

Patients who were class III obese also had increased odds of any complication (OR 1.597; $P < 0.001$). Specifically, they had increased renal (OR 1.928; $P = 0.028$) and wound complications (OR 2.644; $P < 0.001$). They also had greater odds of an adverse discharge disposition (OR 1.468; $P < 0.001$), reoperation (OR 1.596; $P = 0.003$), and extended LOS (OR 1.311; $P < 0.001$). Notably, they had increased odds of Clavien–Dindo IV complications (OR 1.42, $P = 0.007$), but no significant difference in mortality. Full results are presented in Figure 5.

Diabetes was associated with 1.243 times greater odds of any complication ($P < 0.001$), including Clavien–Dindo grade IV complications (OR 1.335; $P < 0.001$. These patients had greater odds of cardiac (OR 1.409; $P < 0.001$), renal (OR 1.568; $P < 0.001$), and hematological complications (OR 1.067; $P = 0.005$), but reduced odds of wound complications (OR 0.794; $P = 0.016$). They also had greater odds of adverse discharge (OR 1.215; $P < 0.001$), readmission (OR 1.208; $P < 0.001$), and extended LOS (OR 1.072; $P < 0.001$). Full results are presented in Figure 6.

The hypertension cohort had 1.226 times greater odds of any complication ($P < 0.001$), including greater cardiac (OR 1.355; $P < 0.001$), pulmonary (OR 1.1; $P = 0.008$), renal (OR 1.488; $P < 0.001$), and hematological complications (OR 1.141; $P < 0.001$). They also had greater odds of life-threatening complications (OR 1.253; $P < 0.001$). These patients also had increased odds of an adverse discharge (OR 1.225; $P < 0.001$) and readmission (OR 1.164; $P < 0.001$). Full results are presented in Figure 7.

Neither hypertension nor diabetes had a significant impact on mortality; however, both MetS and obesity did not. We plotted in hospital survivorship out to 3 standard deviations of mean LOS for the MetS, obese, and metabolically healthy cohorts to graphically illustrate the reduced mortality. This can be seen in Figure 8. Notably, most patients were discharged within 1 week, where the most significant difference in survivorship is present.

4. Discussion

This study assessed the impact of metabolic syndrome, as well as its individual components (obesity, hypertension, and diabetes mellitus), on outcomes after hip fracture surgery. Overall, our findings were somewhat mixed. Although MetS significantly increased postoperative complications, it was associated with reduced 30-day mortality. We can attribute this reduction in mortality to obesity. When analyzing obesity independently, we found similar results: an increase in complications, but a paradoxical reduction in mortality. By contrast, neither

TABLE 2.

Full Postoperative Outcomes for MetS Versus Non-MetS Patients

Variable	MetS	No MetS	Total	P
Postoperative				
Any complication	4286 (86.8)	73,018 (80.8)	77,304 (81.08)	**<0.001**
Cardiac complication	173 (3.5)	2108 (2.3)	2281 (2.39)	**<0.001**
Cardiac arrest requiring CPR	61 (1.2)	651 (0.7)	712 (0.75)	**<0.001**
Myocardial infarction	123 (2.5)	1547 (1.7)	1670 (1.75)	**<0.001**
Pulmonary complication	284 (5.8)	4609 (5.1)	4893 (5.13)	**0.045**
Pneumonia	188 (3.8)	3323 (3.7)	3511 (3.68)	0.655
Pulmonary embolism	41 (0.8)	716 (0.8)	757 (0.79)	0.828
On ventilator greater than 48h	59 (1.2)	492 (0.5)	551 (0.58)	**<0.001**
Unplanned intubation	94 (1.9)	1028 (1.1)	1122 (1.18)	**<0.001**
Hematological complication	1161 (23.5)	20,314 (22.5)	21,475 (22.53)	0.087
Bleeding requiring transfusion	1118 (22.7)	19,650 (21.7)	20,768 (21.78)	0.132
Deep vein thrombosis	58 (1.2)	947 (1.0)	1005 (1.05)	0.433
Renal complication	92 (1.9)	603 (0.7)	695 (0.73)	**<0.001**
Progressive renal insufficiency	54 (1.1)	336 (0.4)	390 (0.41)	**<0.001**
Acute renal failure	38 (0.8)	270 (0.3)	308 (0.32)	**<0.001**
Wound complication	109 (2.2)	1084 (1.2)	1193 (1.25)	**<0.001**
Wound disruption	9 (0.2)	74 (0.1)	83 (0.09)	**0.037**
Superficial incisional SSI	63 (1.3)	690 (0.8)	753 (0.79)	**<0.001**
Deep incisional SSI	22 (0.4)	169 (0.2)	191 (0.20)	**<0.001**
Organ/space SSI	23 (0.5)	196 (0.2)	219 (0.23)	**0.001**
Clavien–Dindo IV complication*	323 (6.5)	4367 (4.8)	4690 (4.92)	**<0.001**
Stroke/cerebral vascular accident	29 (0.6)	701 (0.8)	730 (0.77)	0.165
Septic shock	55 (1.1)	515 (0.6)	570 (0.60)	**<0.001**
Sepsis	67 (1.4)	930 (1.0)	997 (1.05)	**0.032**
Urinary tract infection	237 (4.8)	3420 (3.8)	3657 (3.84)	**<0.001**
Discharge destination				**<0.001**
Home	880 (17.8)	22,080 (24.4)	22,960 (24.08)	
Nonhome	4055 (82.2)	68,323 (75.6)	72,378 (75.92)	
Mortality	186 (3.8)	4398 (4.9)	4584 (4.81)	**0.001**
30-d readmission	496 (10.1)	7367 (8.1)	7863 (8.25)	**<0.001**
30-d unplanned reoperation	164 (3.3)	2179 (2.4)	2343 (2.46)	**<0.001**
Length of stay				**<0.001**
>5 d	3108 (63.0)	50,359 (55.7)	53,467 (56.08)	
0–5 d	1827 (37.0)	40,044 (44.3)	41,871 (43.92)	

Boldface values indicate statistical significance ($P < 0.05$).
* Clavien–Dindo IV complications also include cardiac arrest, myocardial infarction, acute renal failure, stroke, sepsis, and pulmonary embolism.

hypertension nor diabetes significantly altered mortality; however, both were associated with a significant increase in complications, including Clavien–Dindo IV (life-threatening) complications. Most notably, these findings suggest that obesity imparts some mortality reducing protection—that extends to patients with MetS—in the context of operative hip fracture management.

Our findings are consistent with the current literature on the subject. The greater risk of complications in patients with MetS is well documented in both orthopaedic surgery[35,37–41] and other surgical fields.[32,42–45] Cichos et al,[46] in a similar study assessing perioperative outcomes in hip fracture, found MetS increased complications, but reduced mortality. However, they proposed that this reduced mortality may be due to differences in nutrition status, positing MetS patients benefiting from "overnutrition" resulting in higher albumin levels. This, they suggested, may make patients with MetS less susceptible to the poor outcomes associated with hypoalbuminemia and more resistant to the catabolic demands of trauma in the perioperative period. However, we found no significant differences in the baseline rates of hypoalbuminemia between groups. Furthermore, research has actually linked obesity to hypoalbuminemia,[47] making this explanation less plausible.

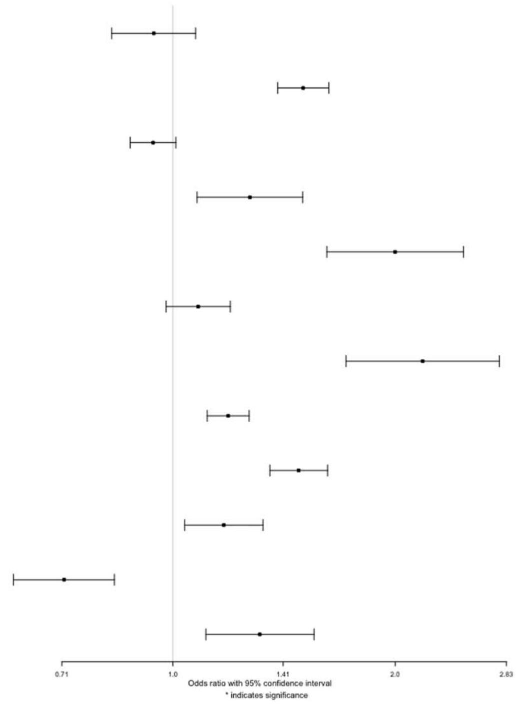
Tracy et al,[48] reporting the outcomes of orthopaedic operative trauma as a whole, had similar findings. Although they lacked our component-based analysis, they also suggested the reduced mortality was due to obesity. They suggested that this mortality reduction may be limited to appendicular surgery or orthopaedics, as increased adiposity may have a less profound effect relative to operations involving the abdominal or thoracic cavity. However, multiple studies report similar findings in cardiac surgery,[49–51] suggesting the obesity paradox extends beyond the musculoskeletal system. Our findings indicate that an underlying physiological difference in obese patients, both with and without MetS, is responsible for this reduced mortality. Regardless of the mechanism, our study offers a more robust assessment of this phenomenon by establishing a concrete, quantitative link between obesity and the improved survival in patients with MetS.

This conclusion is not without precedent; multiple studies have found improved outcomes in obese patients, commonly referred to as the "obesity paradox" in the literature.[52] Our analysis went a step further; we stratified all obese patients into classes. This revealed an apparent limitation of the protective effect. We found that as obesity increases (ie, from class I to class III), the odds of complications trended higher and, eventually, the reduction in mortality was no longer significant. Specifically, in class III obesity, mortality was no longer significantly different than the general population. Still, it is quite notable that, despite a large increase in complications including life-threatening ones, there was no increase in mortality, suggesting an atypical robustness in this population.

These findings are consistent with published literature on the subject. Akinleye et al[53] found that extremes of BMI, both at the upper (morbidly obese with a BMI $>$ 40) and lower ends (underweight with a BMI $<$ 20), were at the greatest risk of complications in hip fracture surgery. Modig et al[52] found that those with a BMI less than 22 had increased postoperative mortality and adverse outcomes. They also had the lowest 1-year survival, even compared with obese patients. This is consistent with our findings, which suggest higher survivorship, relative to healthy weight patients, in both classes I and II obesity. These findings not only suggest that obese patients are not as high risk as conventional wisdom would predict but also indicates that the trends we observed may be valid longitudinally.

Still, the impacts of obesity are not all positive. In an analysis of patients with components of MetS, Gandhi et al[54] found that obesity was a strong predictor of poor functional outcomes in both knee and hip arthroplasty. They attributed this finding to the proinflammatory state associated with metabolic disarrangement. Furthermore, obesity is strongly associated with osteoarthritis[55] and the subsequent need for arthroplasty, both at a younger age and with increased risk of complications, particularly infection, and the need for revision.[55–59] Conspicuously absent, however, were the findings of increased perioperative mortality among obese patients. In a study similar to our own, Della Valle et al found reduced mortality in patients with MetS undergoing total joint arthroplasty, indicating this trend is consistent in orthopaedics, even outside of trauma.[40]

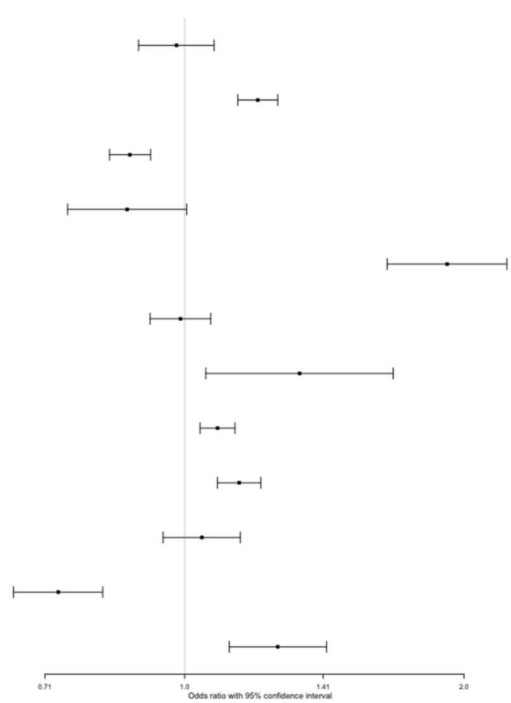
Our results, due to an exceptional sample size, benefit from exceptional statistical power relative to other extant papers on the



Complication	OR	95% C.I Lower	95% C.I Upper	P
Pulmonary Complication	0.942	0.826	1.073	0.366
Discharge Dispostion	1.501	1.386	1.626	<0.001 *
Hematological Complication	0.94	0.875	1.009	0.088
Cardiac Complication	1.271	1.078	1.499	0.004 *
Wound Complication	2	1.616	2.475	<0.001 *
Readmission	1.082	0.979	1.196	0.123
Renal Complication	2.179	1.716	2.768	<0.001 *
Total Length of Hospital Stay Greater Than 5 Days	1.188	1.113	1.268	<0.001 *
Any Complication	1.48	1.353	1.62	<0.001 *
Clavien Dindo IV Life Threatening Complication	1.172	1.037	1.324	0.011 *
Mortality	0.712	0.608	0.833	<0.001 *
Return to OR Within 30 days	1.311	1.108	1.553	0.002 *

Figure 1. Forest plot of outcomes associated with metabolic syndrome.

subject. This gives us heightened confidence in our conclusions. Furthermore, our component-based analysis of MetS and hip fractures allows a better characterization of the risk associated with each respective comorbidity. To the best of our knowledge, this is a novel approach that no other study on hip fractures has taken. While reduced mortality has been observed in both the context of MetS and obesity, our study provides unique, quantitative evidence linking these 2 phenomena. While there is



Complication	OR	95% C.I Lower	95% C.I Upper	P
Pulmonary Complication	0.98	0.892	1.076	0.669
Discharge Dispostion	1.199	1.141	1.26	<0.001 *
Hematological Complication	0.873	0.83	0.919	<0.001 *
Cardiac Complication	0.867	0.748	1.005	0.058
Wound Complication	1.918	1.653	2.225	<0.001 *
Readmission	0.99	0.918	1.067	0.786
Renal Complication	1.33	1.054	1.678	0.016 *
Total Length of Hospital Stay Greater Than 5 Days	1.085	1.039	1.133	<0.001 *
Any Complication	1.145	1.085	1.208	<0.001 *
Clavien Dindo IV Life Threatening Complication	1.044	0.948	1.148	0.382
Mortality	0.731	0.654	0.816	<0.001 *
Return to OR Within 30 days	1.26	1.117	1.422	<0.001 *

Figure 2. Forest plot of outcomes associated with obesity.

Complication	OR	95% C.I Lower	95% C.I Upper	P
Pulmonary Complication	1.009	0.905	1.124	0.878
Discharge Dispostion	1.154	1.089	1.222	<0.001 *
Hematological Complication	0.851	0.802	0.904	<0.001 *
Cardiac Complication	0.775	0.647	0.929	0.006 *
Wound Complication	1.656	1.382	1.984	<0.001 *
Readmission	0.946	0.866	1.034	0.221
Renal Complication	1.39	1.063	1.816	0.016 *
Total Length of Hospital Stay Greater Than 5 Days	1.064	1.012	1.118	0.016 *
Any Complication	1.092	1.026	1.161	0.006 *
Clavien Dindo IV Life Threatening Complication	1.011	0.904	1.132	0.845
Mortality	0.739	0.65	0.84	<0.001 *
Return to OR Within 30 days	1.098	0.946	1.275	0.217

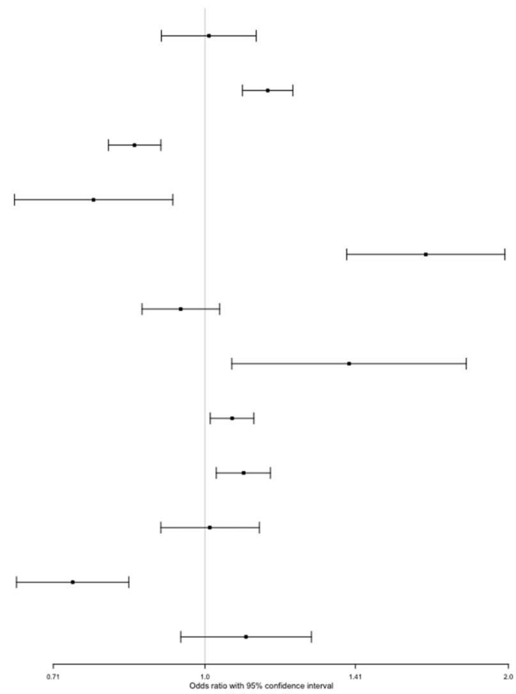


Figure 3. Forest plot of outcomes associated with type 1 obesity.

still uncertainty regarding the physiological mechanism of this protection, our study provides compelling evidence that is related to obesity. Future research exploring the interplay of adiposity, metabolic syndrome, and orthopaedic outcomes is required to explicate the mechanisms behind this protection. We theorize there may be a biomechanical and/or biochemical component to the protection found that should be examined to understand the underlying mechanism.

Complication	OR	95% C.I Lower	95% C.I Upper	P
Pulmonary Complication	0.913	0.738	1.129	0.4
Discharge Dispostion	1.267	1.136	1.412	<0.001 *
Hematological Complication	0.838	0.748	0.938	0.002 *
Cardiac Complication	1.055	0.779	1.427	0.731
Wound Complication	2.411	1.826	3.183	<0.001 *
Readmission	1.168	1	1.363	0.049 *
Renal Complication	1.065	0.609	1.863	0.825
Total Length of Hospital Stay Greater Than 5 Days	1.088	0.994	1.192	0.068
Any Complication	1.168	1.039	1.313	0.009 *
Clavien Dindo IV Life Threatening Complication	1.068	0.867	1.315	0.538
Mortality	0.719	0.56	0.923	0.01 *
Return to OR Within 30 days	1.709	1.361	2.147	<0.001 *

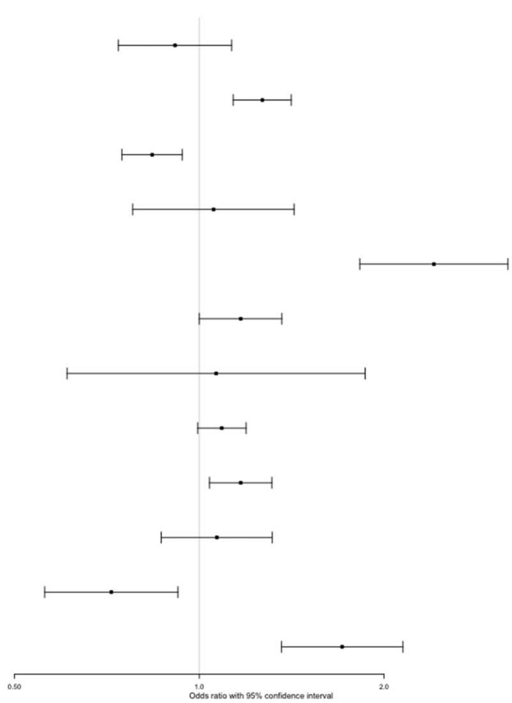
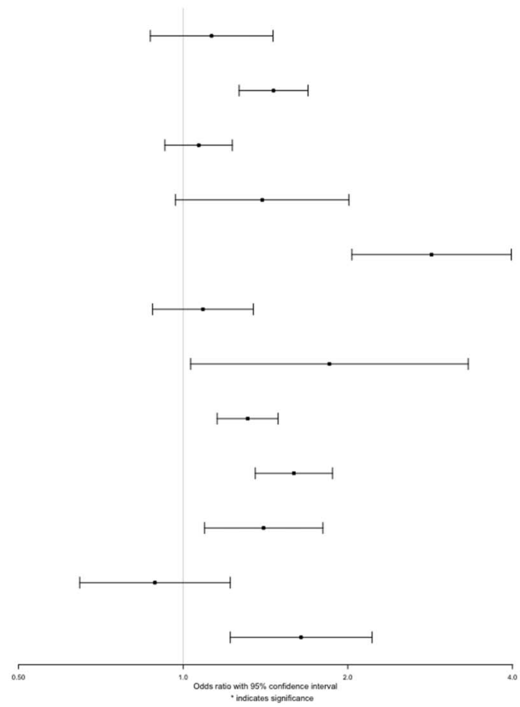


Figure 4. Forest plot of outcomes associated with type 2 obesity.

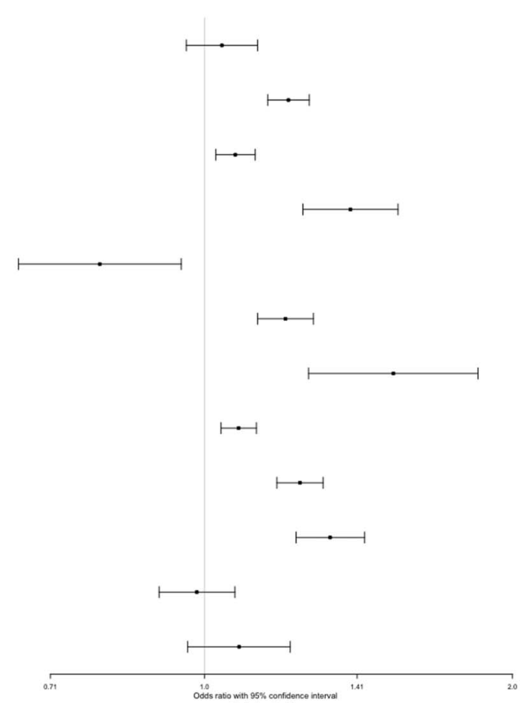


Complication	OR	95% C.I Lower	95% C.I Upper	P
Pulmonary Complication	1.127	0.871	1.46	0.363
Discharge Dispostion	1.463	1.266	1.692	<0.001 *
Hematological Complication	1.068	0.926	1.23	0.366
Cardiac Complication	1.395	0.968	2.009	0.074
Wound Complication	2.846	2.035	3.981	<0.001 *
Readmission	1.087	0.879	1.344	0.441
Renal Complication	1.851	1.032	3.321	0.039 *
Total Length of Hospital Stay Greater Than 5 Days	1.312	1.154	1.491	<0.001 *
Any Complication	1.594	1.355	1.875	<0.001 *
Clavien Dindo IV Life Threatening Complication	1.403	1.094	1.801	0.008 *
Mortality	0.888	0.647	1.219	0.463
Return to OR Within 30 days	1.643	1.219	2.215	0.001 *

Figure 5. Forest plot of outcomes associated with type 3 obesity.

4.1. Limitations

As with any study, ours is not without limitations. First, this is a retrospective study from a large, national database primarily includes academic hospitals, potentially limiting the generalizability of our findings. While we benefit from exceptional sample size, the ACS-NSQIP lacks several variables that may limit our conclusions. We lacked access to data on outcomes beyond 30 days as well as functional outcomes. This is particularly important in hip fractures, as there is significant 1-year mortality and long-term disability. We also lacked patient-reported



Complication	OR	95% C.I Lower	95% C.I Upper	P
Pulmonary Complication	1.04	0.96	1.127	0.339
Discharge Dispostion	1.208	1.153	1.266	<0.001 *
Hematological Complication	1.072	1.026	1.121	0.002 *
Cardiac Complication	1.389	1.248	1.546	<0.001 *
Wound Complication	0.79	0.658	0.949	0.012 *
Readmission	1.2	1.127	1.278	<0.001 *
Renal Complication	1.53	1.264	1.851	<0.001 *
Total Length of Hospital Stay Greater Than 5 Days	1.08	1.038	1.124	<0.001 *
Any Complication	1.24	1.177	1.306	<0.001 *
Clavien Dindo IV Life Threatening Complication	1.327	1.229	1.434	<0.001 *
Mortality	0.983	0.903	1.071	0.698
Return to OR Within 30 days	1.081	0.963	1.213	0.188

Figure 6. Forest plot of outcomes associated with diabetes.

Complication	OR	95% C.I Lower	95% C.I Upper	P
Pulmonary Complication	1.096	1.024	1.173	0.008 *
Discharge Dispostion	1.214	1.173	1.256	<0.001 *
Hematological Complication	1.135	1.095	1.176	<0.001 *
Cardiac Complication	1.353	1.218	1.502	<0.001 *
Wound Complication	0.969	0.85	1.105	0.638
Readmission	1.164	1.102	1.229	<0.001 *
Renal Complication	1.455	1.189	1.78	<0.001 *
Total Length of Hospital Stay Greater Than 5 Days	1.02	0.99	1.052	0.198
Any Complication	1.217	1.173	1.263	<0.001 *
Clavien Dindo IV Life Threatening Complication	1.241	1.156	1.333	<0.001 *
Mortality	0.945	0.882	1.013	0.111
Return to OR Within 30 days	1.002	0.913	1.101	0.959

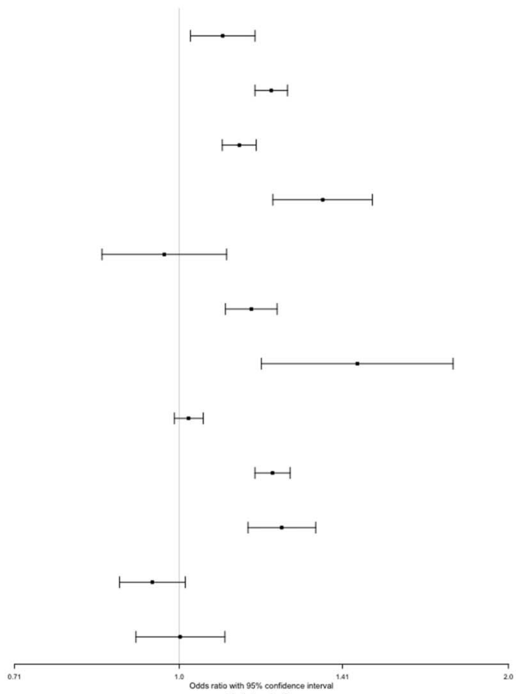


Figure 7. Forest plot of outcomes associated with hypertension.

outcomes and data on important factors such as fracture patterns, exact mechanism of injury, insurance status, and socioeconomic status, which may affect outcomes. In addition, our modified diagnostic criteria for MetS lacked a number of other important markers of metabolic dysfunction, such as a diagnosis of dyslipidemia or pertinent laboratory value data. Each of these factors is important because of their interrelated pathophysiology.[16] Finally, we used BMI instead of central adiposity. Although BMI is a widely used proxy, it does not differentiate between lean body mass and adipose tissue, making us unable to definitely attribute our results to a single patient characteristic.

5. Conclusion

Patients with MetS experienced far more complications but enjoyed reduced mortality. Our component-based analysis of

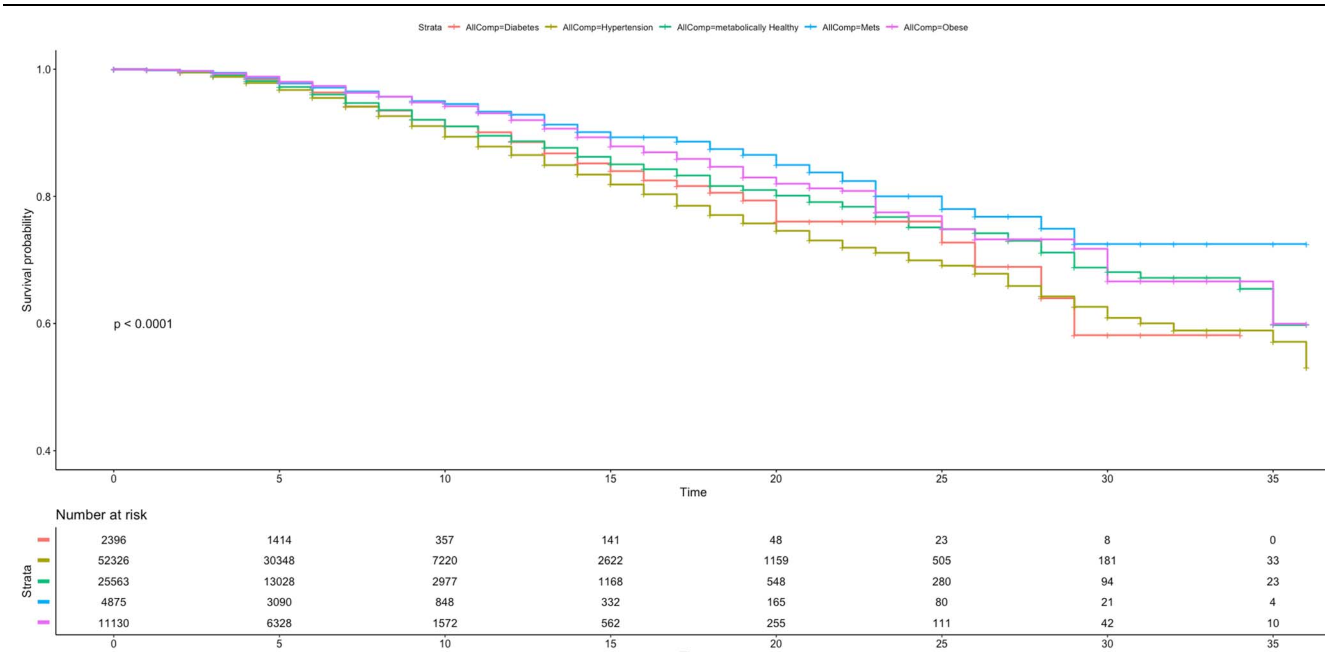


Figure 8. Kaplan–Meier plot of 30-day survivorship.

MetS (assessing the impact of obesity, hypertension, and diabetes individually) suggests that a protective effect stemming from obesity, coined the obesity paradox, is the underlying mortality reducing characteristic. Hypertension or diabetes alone both had increased complications, but neither impacted mortality. Although obese patients also had increased complications, they had a paradoxical reduction in mortality that appears to persist in patients with MetS.

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