# Complications and 30-Day Mortality Rate After Hip Fracture Surgery in Superobese Patients

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**Objective:** Paradoxically, overweight and obesity are associated with lower odds of complications and death after hip fracture surgery. Our objective was to determine whether this "obesity paradox" extends to patients with "superobesity." In this study, we compared rates of complications and death among superobese patients with those of patients in other body mass index (BMI) categories.

**Methods:** Using the National Surgical Quality Improvement Program database, we identified >100,000 hip fracture surgeries performed from 2012 to 2018. Patients were categorized as underweight (BMI <18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25–29.9), obese (BMI 30–39.9), morbidly obese (BMI 40–49.9), or superobese (BMI ≥50). We analyzed patient characteristics, surgical characteristics, and 30-day outcomes. Using multivariate regression with normal-weight patients as the referent, we determined odds of major complications, minor complications, and death within 30 days by BMI category.

**Results:** Of 440 superobese patients, 20% had major complications, 33% had minor complications, and 5.2% died within 30 days after surgery. When comparing patients in other BMI categories with normal-weight patients, superobese patients had the highest odds of major complications [odds ratio (OR): 1.6, 95% confidence interval (CI), 1.2–2.0] but did not have significantly different odds of death (OR: 0.91, 95% CI, 0.59–1.4) or minor complications (OR: 1.2, 95% CI, 0.94–1.4).

**Conclusion:** Superobese patients had significantly higher odds of major complications within 30 days after hip fracture surgery compared with all other patients. This "obesity paradox" did not apply to superobese patients.

**Key Words:** body mass index, complications, hip fracture, mortality, superobesity

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## INTRODUCTION

Obesity is a growing epidemic in the United States, with 78% of Americans projected to be overweight or obese by 2030.[1] Moreover, the number of patients with a body mass index (BMI) value ≥50 kg/m$^2$ (in this article, "superobese") is growing faster than that in any other BMI category.[2] Studies have shown poor outcomes for patients with superobesity after general surgery, cardiac procedures, and total joint arthroplasty[3–7] but, to the best of our knowledge, no such studies have reported on hip fractures in patients with superobesity. As the population continues to age,[8] understanding the risk factors for hip fracture patients is imperative.

For most surgical procedures, higher BMI is associated with higher rates of morbidity and death.[9,10] However, recent studies have documented an "obesity paradox": a seemingly protective effect of overweight and obesity against poor outcomes after certain surgical procedures.[11,12] For example, studies have shown lower rates of morbidity and death for obese patients after surgical fixation of hip fractures compared with normal-weight patients.[13,14]

The purpose of this study was to determine whether this "obesity paradox" extends to patients with "superobesity" by comparing rates of complications and death among superobese patients with those of patients in other BMI categories. We hypothesized that the obesity paradox seen in overweight and obese patients would not be present in superobese patients.

## METHODS

This study was approved by our institutional review board.

### Data Source

We retrospectively reviewed all 105,015 hip fracture surgeries performed between January 1, 2012, and December 31, 2018, recorded in the American College of Surgeons' National Surgical Quality Improvement Program (NSQIP) database. NSQIP is a validated database representing more than 500 hospitals across the United States and containing data on more than 150 surgical variables collected by trained surgical and clinical reviewers.[15] We identified hip fracture fixation procedures using *Current Procedural Terminology*

codes 27125, 27236, 27244, and 27245.[16] We excluded 547 cases performed for hip osteoarthritis (*International Classification of Diseases, Ninth Revision* code 715 and *International Classification of Diseases, 10th Revision* code M16), resulting in 104,468 cases included in this study.

## Patient Variables

We extracted data on preoperative patient characteristics (age, sex, race/ethnicity, BMI, American Society of Anesthesiologists physical status classification, comorbidities, and functional status). Functional status is categorized in NSQIP as independent (does not require assistance from others for any activities of daily living), partially dependent (requires some assistance from another for activities of daily living), or totally dependent (requires total assistance for all activities of daily living).[17] We treated age as a categorical variable as follows: <65, 65–79, 80–89, and ≥90 years. Patients were assigned to groups according to established BMI categories[5,18]: underweight (BMI <18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25–29.9), obese (BMI 30–39.9), morbidly obese (BMI 40–49.9), and superobese (BMI ≥50). By BMI category, 8.9% of procedures were performed for underweight patients, 48% for normal-weight patients, 28% for overweight patients, 14% for obese patients, 1.4% for morbidly obese patients, and 0.4% (n = 440) for superobese patients (Table 1). Thirty-one percent of patients were men. Superobese patients were younger ($P < 0.001$), with 31% of superobese patients younger than 65 years. The distributions of BMI categories were significantly different by patient race/ethnicity ($P < 0.001$).

A modified Charlson Comorbidity Index (mCCI) was developed using available comorbidity data in a similar method to previous NSQIP studies.[19–21] The following point values were assigned to each comorbidity and summed for each patient: history of congestive heart failure (1 point), chronic obstructive pulmonary disease (1 point), diabetes mellitus (1 point), end-stage renal disease (2 points), ascites (3 points), and disseminated cancer (6 points). Previous literature has suggested that mCCIs such as this have had similar predictive ability to that of the original index.[22] Diabetes, dialysis dependence, and congestive heart failure were significantly more common in patients with higher BMI (all, $P < 0.001$; Table 2). Modified CCI was significantly different across BMI categories ($P < 0.001$), with the highest mean (±SD) mCCI values among morbidly obese ($1.0 \pm 1.5$) and superobese ($1.0 \pm 1.6$) patients. The relationships of smoking and chronic obstructive pulmonary disease with a BMI category demonstrated U-shaped curves with increasing BMI (all, $P < 0.001$).

## Surgical Variables

We assessed the following surgical variables: time from hospital admission until surgery, type of anesthesia, and surgical duration. Sixteen percent of procedures were hemiarthroplasty (Table 3). Patients with higher BMI had higher rates of surgery performed >48 hours after hospital admission and general anesthesia administration (both, $P < 0.001$). The mean surgical duration increased linearly with increasing BMI ($P < 0.001$).

## Outcomes of Interest

We assessed complications, including hospital readmissions, reoperations, and prolonged hospitalization (at 30 days after surgery), and death occurring within 30 days after surgery. Complications were classified as major or minor according to previous studies using NSQIP data.[23,24] Minor complications were urinary tract infection (UTI), pneumonia, superficial surgical site infection, and blood transfusion. Major complications were hospital readmission, reoperation, sepsis, septic shock, deep vein thrombosis, pulmonary embolism, stroke or cerebrovascular accident, intubation, renal insufficiency, myocardial infarction, cardiac arrest, wound dehiscence, and deep wound infection. Complications were

**TABLE 1.** Demographic Characteristics of Patients Who Underwent Hip Fracture Surgery From 2012 to 2018, by BMI Category*, NSQIP

| | N (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Characteristic†** | **All Patients** | **Underweight** | **Normal Weight** | **Overweight** | **Obese** | **Morbidly Obese** | **Superobese** |
| No. of patients | 104,468 (100) | 9,292 (8.0) | 49,916 (48) | 29,107 (28) | 14,201 (14) | 1,512 (1.4) | 440 (4.2) |
| Age category, y | | | | | | | |
| <65 | 11,540 (11) | 1,047 (11) | 4,806 (9.6) | 3,025 (10) | 2,104 (15) | 420 (28) | 138 (31) |
| 65–79 | 29,860 (29) | 2,276 (25) | 12,206 (25) | 8,850 (30) | 5,699 (40) | 680 (45) | 149 (34) |
| 80–89 | 41,081 (39) | 3,631 (39) | 20,315 (41) | 11,826 (41) | 4,875 (34) | 323 (21) | 111 (25) |
| ≥90 | 21,987 (21) | 2,338 (25) | 12,589 (25) | 5,406 (19) | 1,523 (11) | 89 (5.9) | 42 (9.6) |
| Male sex | 32,067 (31) | 1,718 (19) | 14,464 (29) | 10,745 (37) | 4,648 (33) | 362 (24) | 130 (30) |
| Race/ethnicity | | | | | | | |
| White | 77,188 (74) | 6,632 (71) | 36,617 (73) | 21,728 (75) | 10,758 (76) | 1,125 (74) | 328 (75) |
| Hispanic | 15,992 (15) | 1,492 (16) | 7,850 (16) | 4,372 (15) | 1,979 (14) | 230 (15) | 69 (16) |
| Black | 3,812 (3.7) | 438 (4.7) | 1,782 (3.6) | 975 (3.4) | 516 (3.6) | 79 (5.2) | 22 (5.0) |
| Asian | 2,644 (2.5) | 382 (4.1) | 1,543 (3.1) | 537 (1.8) | 173 (1.2) | 8 (0.5) | 1 (0.2) |
| Unknown | 4,832 (4.6) | 348 (3.8) | 2,124 (4.3) | 1,495 (5.1) | 775 (5.5) | 70 (4.6) | 20 (4.6) |

*BMI categories defined as follows: underweight, <18.5; normal weight, 18.5–24.9; overweight, 25.0–29.9; obese, 30.0–39.9; morbidly obese, 40.0–49.9; and super obese, ≥50.
†$P < 0.001$ for difference in each characteristic among BMI groups.

**TABLE 2.** Preoperative Characteristics of Patients Who Underwent Hip Fracture Surgery From 2012 to 2018, by BMI Category*, NSQIP

| | N (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Characteristic†** | **All Patients (n = 104,468)** | **Underweight (n = 9,292)** | **Normal Weight (n = 49,916)** | **Overweight (n = 29,107)** | **Obese (n = 14,201)** | **Morbidly Obese (n = 1,512)** | **Superobese (n = 440)** |
| ASA-PS class | | | | | | | |
| 1 | 891 (0.85) | 45 (0.48) | 503 (1.0) | 261 (0.90) | 76 (0.54) | 5 (0.33) | 1 (0.23) |
| 2 | 17,919 (17) | 1,301 (14) | 8,783 (18) | 5,397 (19) | 2,235 (16) | 160 (11) | 43 (9.8) |
| 3 | 65,806 (63) | 5,814 (63) | 31,276 (63) | 18,226 (63) | 9,231 (65) | 995 (66) | 264 (60) |
| 4 | 19,597 (19) | 2,100 (23) | 9,237 (19) | 5,158 (18) | 2,627 (18) | 344 (23) | 131 (30) |
| 5 | 119 (0.11) | 19 (0.21) | 52 (0.10) | 28 (0.10) | 16 (0.11) | 4 (0.27) | 0 (0) |
| Missing | 136 (0.13) | 13 (0.14) | 65 (0.13) | 37 (0.13) | 16 (0.11) | 4 (0.26) | 1 (0.23) |
| Modified CCI value | 0.57 ± 1.3‡ | 0.50 ± 1.2‡ | 0.49 ± 1.2‡ | 0.59 ± 1.2‡ | 0.81 ± 1.4‡ | 1.0 ± 1.5‡ | 1.0 ± 1.6‡ |
| Diabetes | 19,187 (18) | 707 (7.6) | 6,633 (13) | 6,436 (22) | 4,615 (32) | 626 (41) | 170 (39) |
| Dialysis dependent | 2,097 (2.0) | 124 (1.3) | 900 (1.8) | 665 (2.3) | 354 (2.5) | 41 (2.7) | 13 (3.0) |
| CHF | 3,874 (3.7) | 280 (3.0) | 1,654 (3.3) | 1,137 (3.9) | 695 (4.9) | 82 (5.4) | 26 (5.9) |
| Current smoker, within 1 y | 13,041 (12) | 2,068 (22) | 6,522 (13) | 2,805 (9.6) | 1,407 (9.9) | 170 (11) | 69 (16) |
| COPD | 11,837 (11) | 1,623 (17) | 5,386 (11) | 2,847 (9.8) | 1,676 (12) | 233 (15) | 72 (16) |
| Dyspnea | | | | | | | |
| None | 96,652 (93) | 8,470 (91) | 46,560 (93) | 27,026 (93) | 12,898 (91) | 1,331 (88) | 367 (83) |
| With moderate exertion | 6,597 (6.3) | 652 (7.0) | 2,835 (5.7) | 1,802 (6.2) | 1,092 (7.7) | 151 (10) | 65 (15) |
| At rest | 1,219 (1.2) | 170 (1.8) | 521 (1.0) | 279 (0.96) | 211 (1.5) | 30 (2.0) | 8 (1.8) |
| Chronic steroid use | 5,814 (5.6) | 541 (5.8) | 2,624 (5.3) | 1,537 (5.3) | 958 (6.7) | 120 (7.9) | 34 (7.7) |
| Bleeding disorder | 16,793 (16) | 1,044 (11) | 7,430 (15) | 5,200 (18) | 2,781 (20) | 281 (19) | 57 (13) |
| Disseminated cancer | 3,282 (3.1) | 286 (3.1) | 1,408 (2.8) | 880 (3.0) | 607 (4.3) | 77 (5.1) | 24 (5.5) |
| Preoperative functional status | | | | | | | |
| Independent | 81,911 (78) | 6,819 (73) | 38,442 (77) | 23,330 (80) | 11,718 (83) | 1,251 (83) | 351 (80) |
| Partially dependent | 18,325 (18) | 1,967 (21) | 9,261 (19) | 4,761 (16) | 2,049 (14) | 211 (14) | 76 (17) |
| Totally dependent | 3,313 (3.2) | 429 (4.6) | 1,771 (3.5) | 762 (2.6) | 306 (2.2) | 37 (2.4) | 8 (1.8) |
| Missing | 919 (0.88) | 77 (0.83) | 442 (0.89) | 254 (0.87) | 128 (0.90) | 13 (0.86) | 5 (1.1) |
| Hematocrit, % | 35 ± 5.3‡ | 34 ± 5.2‡ | 35 ± 5.2‡ | 36 ± 5.4‡ | 36 ± 5.4‡ | 36 ± 5.5‡ | 36 ± 5.1‡ |

ASA-PS, American Society of Anesthesiologists physical status; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.
*BMI categories defined as follows: underweight, <18.5; normal weight, 18.5–24.9; overweight, 25.0–29.9; obese, 30.0–39.9; morbidly obese, 40.0–49.9; and superobese, ≥50.
†$P < 0.001$ for difference in each characteristic among BMI groups.
‡Expressed as mean ± SD.

also categorized as wound-related (superficial surgical site infection, deep wound infection, or wound dehiscence); pulmonary (unplanned reintubation and ventilator required for >48 hours); cardiac (cardiac arrest and myocardial infarction); and thromboembolic (deep vein thrombosis and pulmonary embolism).

## Statistical Methods

We used descriptive statistics to analyze preoperative patient characteristics, surgical characteristics, and postoperative outcomes for differences across BMI categories. Continuous variables are reported as mean ± SD. We used analysis of variance for normally distributed variables and Kruskal–Wallis tests for nonparametric variables. Categorical variables are reported as frequencies and percentages and were analyzed using $\chi^2$ or Fisher exact tests, as appropriate.

Three logistic regression models were constructed to analyze associations between BMI categories and minor complications, major complications, and 30-day mortality rate while controlling for age, sex, mCCI, procedure type, >48-hour delay in surgery, and functional status. These covariates were included in the regression models on the basis of a priori evidence indicating their relationships with morbidity and death.[25,26] Results of the regression model are reported as odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance was set at $P < 0.01$. Statistical analyses were conducted using Stata, version 15.0, software (StataCorp LLC, College Station, TX).

# RESULTS

## Complications

The rates of major, minor, and overall complications, as well as pulmonary complications, transfusions, hospital readmissions, and prolonged hospitalization had U-shaped relationships with BMI ($P < 0.001$, see **Figure**, **Supplemental Digital**

**TABLE 3.** Surgical Characteristics for Patients Who Underwent Hip Fracture Surgery From 2012 to 2018, by BMI Category*, NSQIP

| | N (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| Characteristic† | All Patients (n = 104,468) | Underweight (n = 9,292) | Normal Weight (n = 49,916) | Overweight (n = 29,107) | Obese (n = 14,201) | Morbidly Obese (n = 1,512) | Superobese (n = 440) |
| Procedure type | | | | | | | |
| ORIF | 88,206 (84) | 7,915 (85) | 41,643 (83) | 24,661 (85) | 12,258 (86) | 1,348 (89) | 381 (87) |
| Hemiarthroplasty | 16,262 (16) | 1,377 (15) | 8,273 (17) | 4,446 (15) | 1,943 (14) | 164 (11) | 59 (13) |
| Delayed surgery (>48 h) | 24,463 (23) | 2,124 (23) | 11,485 (23) | 6,708 (23) | 3,602 (25) | 406 (27) | 138 (31) |
| General anesthesia | 77,771 (74) | 6,493 (70) | 36,240 (73) | 22,162 (76) | 11,276 (79) | 1,244 (82) | 356 (81) |
| Surgery duration, min | 68 ± 42‡ | 59 ± 35‡ | 65 ± 38‡ | 71 ± 44‡ | 78 ± 49‡ | 92 ± 57‡ | 97 ± 61‡ |

ORIF, open reduction internal fixation.
*BMI categories defined as follows: underweight, <18.5; normal weight, 18.5–24.9; overweight, 25.0–29.9; obese, 30.0–39.9; morbidly obese, 40.0–49.9; and super obese, ≥50.
†$P < 0.001$ for difference in each characteristic among BMI groups.
‡Expressed as mean ± SD.

**Content 1**, http://links.lww.com/JOT/B270). The rates of wound complications and renal insufficiency increased linearly with increasing BMI ($P < 0.001$). Reoperation rates were similar among underweight, normal-weight, and overweight patients but increased significantly with increasing BMI in higher BMI categories ($P < 0.001$). Rates of thromboembolic complications increased with increasing BMI, except in superobese patients, who had the lowest rate of thromboembolic complications ($P < 0.001$). We found no differences in the rates of cardiac complications ($P = 0.47$) or UTIs ($P = 0.56$) across BMI categories (Table 4).

Superobese patients had the highest odds of major complications compared with normal-weight patients (OR: 1.6, 95% CI, 1.2–2.0; $P < 0.001$) (Table 5; see **Figure**, **Supplemental Digital Content 2**, http://links.lww.com/JOT/B271). Underweight patients (OR: 1.1, 95% CI, 1.1–1.2) and morbidly obese patients (OR: 1.3, 95% CI, 1.1–1.5) also had higher odds of major complications compared with normal-weight patients (both, $P < 0.001$). Patients who were overweight (OR: 0.88, 95% CI, 0.85–0.91; $P < 0.001$) or obese (OR: 0.88, 95% CI, 0.85–0.91; $P < 0.001$) had lower odds of minor complications, whereas underweight patients (OR: 1.2, 95% CI, 1.2–1.3; $P < 0.001$) had higher

**TABLE 4.** Complications and Death Within 30 Days After Hip Fracture Surgery, by BMI Category, NSQIP, 2012–2018

| | N (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| Variable* | All Patients (n = 104,468) | Underweight (n = 9,292) | Normal Weight (n = 49,916) | Overweight (n = 29,107) | Obese (n = 14,201) | Morbidly Obese (n = 1,512) | Superobese (n = 440) |
| Complication category† | | | | | | | |
| Minor | 33,464 (32) | 3,521 (38) | 16,568 (33) | 8,644 (30) | 4,088 (29) | 496 (33) | 147 (33) |
| Major | 14,803 (14) | 1,386 (15) | 6,941 (14) | 4,033 (14) | 2,102 (15) | 253 (17) | 88 (20) |
| Any | 37,084 (35) | 3,739 (40) | 18,164 (36) | 9,722 (33) | 4,701 (33) | 585 (39) | 173 (39) |
| Complication type | | | | | | | |
| Wound | 1,280 (1.2) | 66 (0.71) | 516 (1.0) | 348 (1.2) | 268 (1.9) | 55 (3.6) | 27 (6.1) |
| Pulmonary | 5,131 (4.9) | 607 (6.5) | 2,470 (4.9) | 1,312 (4.5) | 636 (4.5) | 75 (5.0) | 31 (7.0) |
| Cardiac | 2,378 (2.3) | 220 (2.4) | 1,121 (2.2) | 682 (2.3) | 307 (2.2) | 33 (2.2) | 15 (3.4) |
| Thromboembolic | 1,839 (1.8) | 126 (1.4) | 803 (1.6) | 570 (2.0) | 299 (2.1) | 36 (2.4) | 5 (1.1) |
| Renal insufficiency | 792 (0.76) | 44 (0.47) | 297 (0.59) | 256 (0.88) | 161 (1.1) | 26 (1.7) | 8 (1.8) |
| UTI | 4,512 (4.3) | 401 (4.3) | 2,112 (4.2) | 1,276 (4.4) | 628 (4.4) | 70 (4.6) | 25 (5.7) |
| Transfusion | 27,832 (27) | 2,971 (32) | 13,917 (28) | 7,057 (24) | 3,352 (24) | 416 (28) | 119 (27) |
| Reoperation | 2,790 (2.7) | 235 (2.5) | 1,287 (2.6) | 721 (2.5) | 454 (3.2) | 62 (4.1) | 31 (7.0) |
| Hospital readmission | 9,284 (8.9) | 919 (9.9) | 4,465 (8.9) | 2,423 (8.3) | 1,273 (9.0) | 148 (9.8) | 56 (13) |
| Hospital stay ≥30 d | 941 (0.90) | 99 (1.1) | 432 (0.87) | 272 (0.93) | 110 (0.77) | 16 (1.1) | 12 (2.7) |
| Death | 6,491 (6.2) | 856 (9.2) | 3,421 (6.9) | 1,506 (5.2) | 613 (4.3) | 72 (4.8) | 23 (5.2) |

*All $P$ values <0.001, except cardiac complication ($P = 0.47$) and UTI ($P = 0.60$).
†Categories are not mutually exclusive.

**TABLE 5.** Adjusted* Odds of Complications and Death Within 30 Days After Hip Fracture Surgery Among 104,468 Patients, by BMI Category, NSQIP, 2012–2018

| | Death | | Major Complication | | Minor Complication | |
|---|---|---|---|---|---|---|
| **BMI Category†** | **OR (95% CI)** | ***P*** | **OR (95% CI)** | ***P*** | **OR (95% CI)** | ***P*** |
| Normal weight | Referent | | Referent | | Referent | |
| Underweight | 1.5 (1.4–1.6) | <0.001 | 1.1 (1.1–1.2) | <0.001 | 1.2 (1.2–1.3) | <0.001 |
| Overweight | 0.75 (0.70–0.80) | <0.001 | 0.98 (0.94–1.0) | 0.29 | 0.88 (0.85–0.91) | <0.001 |
| Obese | 0.69 (0.63–0.76) | <0.001 | 1.1 (1.0–1.1) | 0.02 | 0.88 (0.84–0.91) | <0.001 |
| Morbidly obese | 0.93 (0.72–1.2) | 0.57 | 1.3 (1.1–1.5) | <0.001 | 1.1 (1.0–1.3) | 0.04 |
| Superobese | 0.91 (0.59–1.4) | 0.66 | 1.6 (1.2–2.0) | <0.001 | 1.2 (0.94–1.4) | 0.17 |

*Adjusted for age category, sex, procedure type, time from admission until surgery, and functional status.
†BMI categories defined as follows: underweight, <18.5; normal weight, 18.5–24.9; overweight, 25.0–29.9; obese, 30.0–39.9; morbidly obese, 40.0–49.9; and superobese, ≥50.

odds of minor complications. Morbidly obese ($P = 0.04$) and superobese ($P = 0.17$) patients did not have significantly higher odds of minor complications compared with normal-weight patients.

## Death

The mortality rate had a U-shaped relationship with BMI, with the highest rates in underweight (9.2%), normal-weight (6.9%), and superobese (5.2%) patients ($P < 0.001$, see **Figure**, **Supplemental Digital Content 1**, http://links.lww.com/JOT/B270). Compared with normal-weight patients, overweight patients (OR: 0.75, 95% CI, 0.70–0.80; $P < 0.001$) and obese patients (OR: 0.69, 95% CI: 0.63–0.76; $P < 0.001$) had lower odds of death, whereas underweight patients had significantly higher odds of death (OR: 1.5, 95% CI, 1.4–1.6; $P < 0.001$). Morbidly obese ($P = 0.57$) and superobese ($P = 0.66$) patients did not have significantly higher odds of death compared with normal-weight patients.

# DISCUSSION

We analyzed rates of morbidity and death in superobese patients within 30 days after surgical fixation of hip fractures and compared their outcomes with those of patients in other BMI categories. On unadjusted analysis, we found the highest rates of wound complications, pulmonary complications, renal insufficiency, UTI, reoperation, hospital readmission, and prolonged hospitalization among superobese patients. After adjustment for potential confounders, superobese patients had the highest odds of major complications. The obesity paradox seen in overweight and obese patients did not occur in morbidly obese or superobese patients.

Our regression model demonstrated that obesity and overweight, but not morbid obesity or superobesity, were associated with lower odds of death compared with normal-weight status. In comparison, underweight patients had the greatest odds of death. Our findings regarding the mortality rates of patients in other BMI categories are similar to those reported in previous studies. Modig et al[13] analyzed a Swedish national registry for hip fracture patients between 2013 and 2016 and categorized BMI as underweight (<22), normal weight (22–25), overweight (25–30), and obese (≥30). The authors found a decrease in the odds of death within 1 year with increasing BMI. Using the normal-weight group as a referent, they found significantly higher odds of death for underweight patients but lower odds of death for overweight and obese patients. Similarly, Prieto-Alhambra et al[27] used a national database of primary care records in Spain and found better 3-year survival rates in overweight and obese hip fracture patients compared with those of normal weight. However, neither of these studies stratified BMI as morbid obesity and/or superobesity for patients whose BMI was ≥30. Akinleye et al[14] assessed NSQIP data from 2008 to 2012, grouping more than 15,000 hip fracture patients into BMI categories of <20, 20–30, 30–40, and ≥40. They reported higher 30-day mortality rates for patients in the lowest and highest BMI categories; however, after adjustment for potential confounders, these differences were no longer significant. A potential explanation for the difference in findings between their study and ours is the difference in BMI categories used. We chose a cutoff of <18.5 kg/m$^2$ based on definitions used by the World Health Organization and the European Society of Clinical Nutrition and Metabolism,[28] whereas Akinleye et al[14] used 20 kg/m$^2$. Moreover, they did not analyze a BMI category of superobese.

We found a U-shaped relationship between BMI categories and major and minor complication rates before and after adjustment for covariates. It was not surprising that underweight patients had greater odds of postoperative complications because previous studies have found an association between frailty or malnutrition and poor surgical outcomes, particularly in geriatric patients.[29,30] However, a novel finding of our study is the prevalence of complications in superobese patients. Although superobesity was not associated with higher odds of minor complications, it was independently associated with major complications. Superobesity was associated with the highest odds of major complications because of higher rates of cardiac complications, renal insufficiency, reoperation, hospital readmission, and prolonged hospitalization. Although, to the best of our knowledge, no studies have analyzed outcomes after surgical repair of hip fractures in superobese patients, our findings are similar to those of studies of superobese patients who have undergone

other orthopaedic procedures. Werner et al[5] used the PearlDiver patient record database (PearlDiver Inc, Fort Wayne, IN) to analyze data from superobese patients who underwent primary total knee arthroplasty. The authors reported 28% and 25% rates of systemic and medical complications, respectively, compared with 3.8% and 3.0% in nonobese patients. A similar study of primary total hip arthroplasty found that superobese patients had 8.2 times the odds of medical complications compared with nonobese patients.[31] In addition to cardiovascular issues, super obesity is associated with intraoperative challenges, such as greater operative difficulty, longer surgical duration, and challenging postoperative wound care. Interestingly, we found a significantly higher rate of major complications among superobese patients but no significant difference in mortality rate. The obesity paradox has been studied in orthopaedics, as well as other specialties, and several theories have been proposed as to why it exists, such as a larger reserve of lean body mass (which is not accounted for in the BMI metric).[32,33] However, the cardiovascular effects of morbid obesity and superobesity may outweigh any such benefit with regard to survival.[34] The superobese and morbidly obese patients in our study did not have the lower odds of death we found among overweight and obese patients, likely because of these higher rates of complications. It is likely that these major complications led to insults to the patients' physiologic reserves.

Our study is subject to several limitations, including those inherent to retrospective analysis. We were able to assess outcomes up to 30 days. This is a limitation of many studies using NSQIP data.[14,35] Further study is needed to determine the long-term outcomes in superobese patients. Although the NSQIP database is a validated research tool and uses clinical reviewers for data abstraction as opposed to administrative claims,[36] some suggest it may not be representative of all hospitals in the United States.[37]

## CONCLUSION

Providers should be aware of the unique risks facing hip fracture patients with superobesity. These patients are at the highest risk for major complications compared with other BMI categories. The lower likelihood of postoperative death seen in patients who are overweight or obese does not seem to extend to patients who are morbidly obese or superobese.

## REFERENCES


1. Wang Y, Beydoun MA, Min J, et al. Has the prevalence of overweight, obesity and central obesity levelled off in the United States? Trends, patterns, disparities, and future projections for the obesity epidemic. *Int J Epidemiol.* 2020;49:810–823.
2. Sturm R, Hattori A. Morbid obesity rates continue to rise rapidly in the United States. *Int J Obes.* 2013;37:889–891.
3. Ponnusamy KE, Somerville L, McCalden RW, et al. Revision rates and functional outcome scores for severely, morbidly, and super-obese patients undergoing primary total hip arthroplasty: a systematic review and meta-analysis. *JBJS Rev.* 2019;7:e11.
4. Rajgopal R, Martin R, Howard JL, et al. Outcomes and complications of total hip replacement in super-obese patients. *Bone Joint J.* 2013;95-B: 758–763.
5. Werner BC, Evans CL, Carothers JT, et al. Primary total knee arthroplasty in super-obese patients: dramatically higher postoperative complication rates even compared to revision surgery. *J Arthroplasty.* 2015;30: 849–853.
6. Gupta M, Dugan A, Chcon E, et al. Detailed Perioperative Risk Among Patients with Extree Obesity Undergoing Nonbariatric General Surgery. *Surgery.* 2020;168:462–470.
7. Tyson GH III, Rodriguez E, Elci OC, et al. Cardiac procedures in patients with a body mass index exceeding 45: outcomes and long-term results. *Ann Thorac Surg.* 2007;84:3–9; discussion 9.
8. Anderson LA, Goodman RA, Holtzman D, et al. Aging in the United States: opportunities and challenges for public health. *Am J Public Health.* 2012;102:393–395.
9. Sayed-Noor AS, Mukka S, Mohaddes M, et al. Body mass index is associated with risk of reoperation and revision after primary total hip arthroplasty: a study of the Swedish hip arthroplasty register including 83,146 patients. *Acta Orthop.* 2019;90:220–225.
10. Turrentine FE, Hanks JB, Schirmer BD, et al. The relationship between body mass index and 30-day mortality risk, by principal surgical procedure. *Arch Surg.* 2012;147:236–242.
11. Hartrumpf M, Kuehnel RU, Albes JM. The obesity paradox is still there: a risk analysis of over 15,000 cardiosurgical patients based on body mass index. *Interact Cardiovasc Thorac Surg.* 2017;25:18–24.
12. Mullen JT, Moorman DW, Davenport DL. The obesity paradox: body mass index and outcomes in patients undergoing nonbariatric general surgery. *Ann Surg.* 2009;250:166–172.
13. Modig K, Erdefelt A, Mellner C, et al. Obesity paradox holds true for patients with hip fracture: a registry-based cohort study. *J Bone Joint Surg Am.* 2019;101:888–895.
14. Akinleye SD, Garofolo G, Culbertson MD, et al. The role of BMI in hip fracture surgery. *Geriatr Orthop Surg Rehabil.* 2018;9: 2151458517747414.
15. Henderson WG, Daley J. Design and statistical methodology of the national surgical quality improvement program: why is it what it is? *Am J Surg.* 2009;198:S19–S27.
16. Sathiyakumar V, Greenberg SE, Molina CS, et al. Hip fractures are risky business: an analysis of the NSQIP data. *Injury.* 2015;46:703–708.
17. Skube SJ, Lindemann EA, Arsoniadis EG, et al. Characterizing functional health status of surgical patients in clinical notes. *AMIA Joint Summits Transl Sci Proc.* 2018;2017:379–388.
18. National Heart L, Blood Institute. *Calculate your body mass index*. Available at www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmi-m.htm. Accessed April 7, 2020.
19. Bohl DD, Basques BA, Golinvaux NS, et al. Extramedullary compared with intramedullary implants for intertrochanteric hip fractures: 30-days outcomes of 4432 procedures from the ACS NSQIP database. *J Bone Joint Surg Am.* 2014;96:1871–1877.
20. Golinvaux NS, Bohl DD, Basques BA, et al. Diabetes confers little to no increased risk of postoperative complications after hip fracture surgery in geriatric patients. *Clin Orthop Relat Res.* 2015;473:1043–1051.
21. Bohl DD, Fu MC, Gruskay JA, et al. July effect in elective spine surgery: analysis of the American College of Surgeons National Surgical Quality Improvement Program database. *Spine.* 2014;39:603–611.
22. D'Hoore W, Bouckaert A, Tilquin C. Practical considerations on the use of the Charlson comorbidity index with administrative data bases. *J Clin Epidemiol.* 1996;49:1429–1433.
23. Molina CS, Thakore RV, Blumer A, et al. Use of the National Surgical Quality Improvement Program in orthopaedic surgery. *Clin Orthop Relat Res.* 2015;473:1574–1581.
24. Suskind AM, Walter LC, Jin C, et al. Impact of frailty on complications in patients undergoing common urological procedures: a study from the American College of Surgeons National Surgical Quality Improvement database. *BJU Int.* 2016;117:836–842.
25. Xu BY, Yan S, Low LL, et al. Predictors of poor functional outcomes and mortality in patients with hip fracture: a systematic review. *BMC Musculoskelet Disord.* 2019;20:568.
26. Seitz DP, Anderson GM, Austin PC, et al. Effects of impairment in activities of daily living on predicting mortality following hip fracture surgery in studies using administrative healthcare databases. *BMC Geriatr.* 2014;14:9.
27. Prieto-Alhambra D, Premaor MO, Aviles FF, et al. Relationship between mortality and BMI after fracture: a population-based study of men and women aged >/=40 years. *J Bone Miner Res.* 2014;29:1737–1744.

28. World Health Organization. *Nutrition landscape information system (NLiS): help topic: malnutrition in women*. Available at: https://pubmed.ncbi.nlm.nih.gov/27642056/. Accessed April 30, 2020.
29. Aldebeyan S, Nooh A, Aoude A, et al. Hypoalbuminaemia-a marker of malnutrition and predictor of postoperative complications and mortality after hip fractures. *Injury.* 2017;48:436–440.
30. Traven SA, Reeves RA, Althoff AD, et al. New five-factor modified frailty index predicts morbidity and mortality in geriatric hip fractures. *J Orthop Trauma.* 2019;33:319–323.
31. Werner BC, Higgins MD, Pehlivan HC, et al. Super obesity is an independent risk factor for complications after primary total hip arthroplasty. *J Arthroplasty.* 2017;32:402–406.
32. Valentijn TM, Galal W, Tjeertes EK, et al. The obesity paradox in the surgical population. *Surgeon.* 2013;11:169–176.
33. Lee DH, Keum N, Hu FB, et al. Predicted lean body mass, fat mass, and all cause and cause specific mortality in men: prospective US cohort study. *BMJ.* 2018;362:k2575.
34. Khan SS, Ning H, Wilkins JT, et al. Association of body mass index with lifetime risk of cardiovascular disease and compression of morbidity. *JAMA Cardiol.* 2018;3:280–287.
35. Arshi A, Rezzadeh K, Stavrakis AI, et al. Standardized hospital-based care programs improve geriatric hip fracture outcomes: an analysis of the ACS NSQIP targeted hip fracture series. *J Orthop Trauma.* 2019;33:e223–e228.
36. McNelis J, Castaldi M. The National Surgery Quality Improvement Project (NSQIP): a new tool to increase patient safety and cost efficiency in a surgical intensive care unit. *Patient Saf Surg.* 2014;8:19.
37. Sheils CR, Dahlke AR, Kreutzer L, et al. Evaluation of hospitals participating in the American College of Surgeons National Surgical Quality Improvement Program. *Surgery.* 2016;160:1182–1188.