Severe Obesity Worsens 30-Day Surgical Outcomes and Projected Costs in Operative Femoral Shaft and Tibial Shaft Fractures

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Objective: To assess the impact of severe obesity on 30-day adverse event rates, hospital length of stay (LOS), readmissions, and projected costs after operative fixation of tibia and femur fractures.

Methods: An analysis of the American College of Surgeons National Surgical Quality Improvement Project database from 2012 to 2019 of isolated femoral shaft and tibial shaft fracture fixation cases was conducted. Adverse events, LOS, readmission rates, and operative time were queried for severe obesity, defined as body mass index greater than 40, compared with other patients. Student *t* tests were used to assess continuous variables. Fisher exact test and odds ratios were used for categorical variables. A cost-analysis was also performed to quantify the effect of severe obesity on projected health care expenditures.

Results: A total of 10,436 patients were included with 7.0% of patients categorized as severely obese. Severely obese patients had higher infectious complication rates (9.0% vs. 6.7%, $P = 0.013$, OR 1.36, 95% CI 1.04–1.78), readmission rates (7.9% vs. 5.6%, *P*-value = 0.008, OR 1.44, 95% CI 1.08–1.91), longer LOS (5.8 days SD ±10.2 vs. 5.0 days SD ±7.9 days, *P*-value = 0.008), and longer operative times (mean 115 minutes ± 56 minutes SD vs. 103 minutes SD ±54 minutes, *P*-value = <0.001). Severe obesity resulted in an estimated $4258.07 additional health care expenditures per patient compared with nonobese patients. This amounted to a projected added total expenditure of $3.09 million USD in the overall cohort.

Conclusion: Severe obesity is associated with significantly worse 30-day outcomes and higher readmission rates for patients undergoing operative fixation of tibial shaft and femoral shaft fractures. Health policy considerations should be made to incentivize care for this patient population, particularly in trauma where modification of risk factors before surgery is often not feasible.

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INTRODUCTION

The obesity epidemic continues to worsen in the United States. From 1999 to 2018, the prevalence of obesity in the United States rose from 30.5% to 42.4%, and the prevalence of severe obesity defined as body mass index (BMI) ≥ 40 rose from 4.7% to 9.2%.[1,2] The association between severe obesity and diabetes, cardiovascular disease, pulmonary disease, peripheral vascular disease, liver disease, pancreatitis, and certain malignancies has been well-documented, but the association of severe obesity with trauma is not as well-understood. Finkelstein et al[3] demonstrated that adults with severe obesity are 48% more likely to sustain a musculoskeletal injury requiring medical treatment than nonobese adults. The treatment of severely obese trauma patients is often complex, with higher rates of infection, increased adverse events, increased operative time, increased radiation usage, longer ICU and hospital length of stay, and increased morbidity and mortality.[4–12] The increasing number of orthopaedic trauma patients with severe obesity and the added complexity of their care have implications in the overall costs of care per patient. With the advent of value-based care and bundled reimbursements, there is renewed interest in understanding the impact of risk factors such as severe obesity on health care expenditures, readmissions, and surgical outcomes.[13,14] This is particularly relevant in orthopaedic trauma where the opportunity to address modifiable risk factors before surgical intervention is seldom feasible.[15]

The purpose of this study was to use a large administrative database to assess the impact of severe obesity on 30-day adverse events, hospital length of stay (LOS), readmissions, and total projected costs after operative fixation of femur and tibial shaft fractures. We hypothesized that the rate of adverse events, length of stay, number of readmissions, and overall expenditures of care would be higher among patients with severe obesity.

METHODS

The American College of Surgeons National Surgical Quality Improvement Project (NSQIP) database spanning

2012–2019 was queried for analysis. Several studies have used NSQIP in the surgical literature, and it is accepted as a high-quality data source.[16,17] It includes more than 200 unique variables and is collected in a prospective fashion from more than 600 participating hospitals.

Cases were identified by Current Procedural Terminology (CPT) codes 27506, 27507, 27758, and 27759 to isolate femoral shaft and tibial shaft fracture fixation cases in adults 18 years of age and older. Polytrauma patients were excluded by filtering out for patients with additional CPT codes, not including removal of external fixator or traction pin procedures. Adverse events, infectious complications, LOS readmission rates, and operative time were queried in patients with severe obesity compared with other patients. The NSQIP database contains more than 300 assorted variables. Adverse events were defined as occurrence of any of 20 complications (see **Table**, **Supplemental Digital Content 1**, http://links.lww.com/JOT/B796). Postoperative complications were further stratified into major adverse events, infectious complications (urinary tract infection, pneumonia, sepsis, septic shock, superficial surgical site infection, or deep SSI) and Clavien–Dindo IV complications (life-threatening complications with end-organ dysfunction). In this data set, Clavien–Dindo IV classifications included postoperative cardiac arrest, myocardial infarction (MI), sepsis, pulmonary embolism, or renal failure.[18] Procedures conducted in the outpatient setting were excluded to create a more uniform cohort of patients. Patients with missing data on outcome variables of interest were omitted from analysis. All statistical analyses were conducted using SPSS (IBM SPSS Statistics for Windows, version 28.0; Armonk, NY: IBM Corp). Paired student *t* tests were used to assess continuous variables. Fisher exact test and odds ratios were used for categorical variables.

To assess costs associated with severe obesity, publicly available cost information from the Agency for Healthcare Research (AHRQ) and Centers for Medicare and Medicaid Services was extracted and applied to cohort occurrence rates of readmission and inpatient hospital stays.[19] The average cost of a readmission used was $15,200, and length of stay expenditures were calculated at $2873 per day consistent with Centers for Medicare and Medicaid Services (CMS) figures. The impact of operative time on health care costs was quantified using methods from a study conducted by Childers et al with a cost of $37 per minute of operative time used for expenditure comparisons.[19] To better estimate the cost impact of severe obesity, weighted-adjusted costs per complication were tabulated for severe obese patients versus patients with normal BMI based on differences in complication incidence. Adjusted costs for these complications were calculated using figures from a comprehensive NSQIP cost analysis conducted by Merkow et al.[20] A summation of added expenditures on average per patient was applied to the overall severe obese cohort. With these figures applied to mean differences in outcomes between the cohorts, estimates for health care expenditure differences attributable to severe obesity were quantified and compared. This analysis was limited to postoperative rates of readmission, unplanned reintubation, extended ventilation requirements, pneumonia, cardiac event, renal failure, and hospital length of stay.

RESULTS

Initially, 6,598,322 patients were identified in the ACS-NSQIP database from 2012 to 2019. After a selection of operative femur and tibia fracture patients and screening of cases with missing data, 10,436 patients were included in this study with 7.0% of patients categorized as severely obese (see **Figure**, **Supplemental Digital Content 2**, http://links.lww.com/JOT/B797). A tabulation of the proportion of obese and severe obese patients over time indicated steadily climbing rates of obesity and severe obesity during the study period (Fig. 1). Demographic univariate comparisons revealed severely obese patients were more likely to be woman, to have a higher modified fragility score, and were less likely to be smokers or identify as Asian (Table 1). In outcomes analysis, severely obese patients had significantly higher infectious complication rates (9.0% vs. 6.7%, P = 0.013, OR 1.36, 95% CI 1.04–1.78), readmission rates (7.9% vs. 5.6%, P-value = 0.008, OR 1.44, 95% CI 1.08–1.91), longer LOS (5.8 days SD ±10.2 vs. 5.0 days SD ±7.9 days, P-value = 0.008), and longer operative times (mean 115 minutes ±56 minutes SD vs. 103 minutes SD ±54 minutes, P-value = <0.001) (Table 2). These differences in outcomes were amplified in a comparison of severely obese patients with patients with normal BMI (18–30) (Table 3).

Cost analysis for select variables revealed severe obesity resulted in an estimated $4258.07 additional health care expenditures per patient on average compared with normal BMI patient. This amounted to an annual projected added expenditure of $365,776.43 and $3.09 million USD in added costs for the cohort during the overall study period (Table 4).

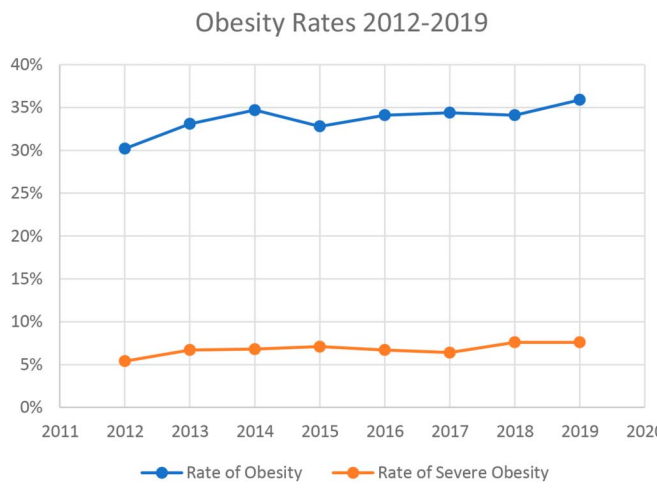

FIGURE 1. Rates of obesity (BMI > 30) and severe obesity (BMI > 40) over time in patients undergoing femoral shaft and tibial shaft operative fixation increased. Percent value corresponds to total operations per year. full color online

TABLE 1. Baseline Demographics and Univariate Analysis of Patient Characteristics

Patients (% Total)	Severe Obesity n = (726)	Other Patients n = (9710)	Odds Ratio, (95% Confidence Interval) *P*
Sex*			
Female*	533 (73.4)	5907 (60.8)	1.78 (1.50–2.11)
Age*	60.2 ± 16.1	62.9 ± 20.4	$P < 0.001$
5-item modified frailty index	1.45 ± 1.07	0.90 ± 0.93	$P < 0.001$
Race*			
Hispanic	51 (7.0)	861 (8.9)	0.78 (0.58–1.04)
Asian*	5 (0.7)	298 (3.1)	0.22 (0.09–0.53)
Black	71 (9.8)	825 (8.5)	1.17 (0.91–1.51)
White*	548 (75.5)	6934 (71.4)	1.23 (1.04–1.47)
Bleeding disorder*			
Yes	107 (14.7)	948 (9.8)	1.56 (1.39–1.98)
Diabetes			
Yes*	1718 (15.9)	329 (42.6)	3.92 (3.37–4.56)
Smoker*			
Yes*	116 (16.0)	1999 (20.6)	0.73 (0.60–0.90)
History of COPD*			
Yes	83 (11.4)	706 (7.3)	1.65 (1.29–2.1)
Renal dialysis*			
Yes	28 (3.9)	177 (1.8)	2.16 (1.44–3.24)

Significant value (*P* value < 0.01).
COPD, chronic obstructive pulmonary disease.
*Indicates statistically significant result.

DISCUSSION

This study demonstrated that severe obesity is associated with significantly worse 30-day outcomes and higher readmission rates for patients undergoing operative fixation of tibial shaft and femoral shaft fractures. The increase in cost and resource utilization associated with the care of obese patients is well-documented across many medical specialties. Hussan et al demonstrated that obesity is linked to an increase in hospitalization costs and an increased disposition to short-term rehabilitation facilities compared with a normal weight status in patients undergoing colorectal surgery.[19] There have been multiple studies examining the association between obesity and perioperative complications in patients with lower extremity fractures. In a large database study, Burrus et al[10] demonstrated that patients with severe obesity have higher rates of major and minor medical complications, infection, venous thromboembolism, and nonunion after operative treatment of tibial shaft fractures. Kempegowda et al[8] reported increased operative time and length of stay in addition to increased rates of systemic complications, adult respiratory distress syndrome, and sepsis in obese patients with operatively treated intertrochanteric femur fractures. They also found that patients with severe obesity (BMI ≥ 40) had a much higher rate of respiratory and wound complications. Weinlein et al[7] reported a 23% systemic complication rate in severely obese patients who underwent surgical treatment of a femoral shaft fracture compared with 9% in normal-weight patients. They also found BMI to be an independent predictor of adult respiratory distress syndrome, sepsis, and death and that the association was even stronger in a subset of polytraumatized patients with an injury severity score > 17. Childs et al[9] reported on a cohort of polytraumatized patients with an injury severity score > 16 and an unstable fracture of the femur, pelvis, or spine and found that patients with obesity had higher overall complications (38% vs. 28%), including acute renal failure (5.7% vs. 1.4%), and infection (11.4% vs. 5.4%). They also reported that obese patients had longer mechanical ventilation times, increased number of days in the ICU, and overall increased length of stay. This is consistent with findings from our study which found higher rates of adverse events, infection, and readmission, as well as longer length of stay and operative time in severely obese patients with operatively treated femoral and tibial shaft fractures. Our study has the benefit of a significantly larger patient cohort than other studies, a merit of large database research. In addition, this is the first study we are aware of that has examined

TABLE 2. Adverse Events and Outcomes Overall Cohort

Patients (% Total)	Severe Obesity n = (726)	Other Patients n = (9710)	Odds Ratio, Interfacility Transfer (95% Confidence Interval)	*P*
Any adverse event	213 (29.3)	2897 (29.8)	0.98 (0.83–1.15)	0.405
Major adverse events	74 (10.2)	833 (8.6)	1.21 (0.94–1.55)	0.078
Clavien–Dindo IV complications	29 (4.0)	301 (3.1)	1.30 (0.88–1.92)	0.111
Mortality	17 (2.3)	317 (3.3)	0.71 (0.43–1.16)	0.105
Infectious complications*	65 (9.0)	653 (6.7)	1.36 (1.04–1.78)	0.013
Readmissions*	57 (7.9)	544 (5.6)	1.44 (1.08–1.91)	0.008
Discharge not home*	442 (60.9)	4601 (47.4)	1.73 (1.48–2.02)	<0.001
Length of stay*	5.8 ± 10.21 d		5.0 d ± 7.9 d	0.008
Operative time*	115 min ± 56 min		103 min ± 54 min	<0.001

Significant value (*P* value < 0.01).
OR, operating room.
*Indicates statistically significant result.

TABLE 3. Adverse Events and Outcomes Severe Obesity Versus Nonobese

Patients (% Total)	Severe Obesity (BMI > 40) n = (726)	Nonobese (BMI 18–30) n = (6500)	Odds Ratio, Interfacility Transfer (95% Confidence Interval)	*P*
Any adverse event	213 (29.3)	1937 (29.8)	0.98 (0.83–1.16)	0.42
Major adverse events	74 (10.2)	541 (8.3)	1.25 (0.97–1.62)	0.05
Clavien–Dindo IV complications	29 (4.0)	19 (3.0)	1.36 (0.91–2.03)	0.08
Mortality	227 (3.5)	17 (2.3)	0.66 (0.40–1.09)	0.06
Infectious complications*	417 (6.4)	65 (9.0)	1.43 (1.09–1.89)	0.007
Readmissions*	57 (7.9)	344 (5.3)	1.53 (1.14–2.04)	0.004
Discharge not home*	442 (60.9)	2975 (45.8)	1.84 (1.58–2.16)	<0.001
Length of stay*	5.8 ± 10.21 d	4.9 d ± 8.2 d		0.008
Operative time*	115 min ± 56 min	101 min ± 54 min		<0.001

*Indicates statistically significant result.

the projected cost-implications of severe obesity on lower extremity fractures. With the advent of bundled care and value-based health policies in the United States, significantly higher health care expenditures associated with severe obesity should be taken into consideration.

The Bundled Payments for Care Improvement implemented by the Center for Medicare and Medicaid Services began in 2015 to reduce excess health care expenditures. The shift toward quality and outcome-based reimbursement has relevance to our findings. It has been shown that these bundled payments may cause a disproportionate decrease in reimbursement when treating patients with increasingly complex medical comorbidities.[21,22] Because hospitals are receiving bundled payments regardless of patient demographics, such as weight status, there is a distinct need for stratification of penalties to avoid excess penalization as obesity complicates standard management. Smith et al demonstrated that although hospitals received an increase in compensation for treatment of obese patients undergoing total hip arthroplasty, the increase in expenditure was far greater.[22] As the proportion of adults in the United States who are obese rises, better characterizing the association between obesity and operative complications is critical. Quality-driven reimbursement, especially applied in these populations, can avoid inadvertently disincentivizing surgical management and should be taken into consideration for obese patients undergoing surgery for lower extremity fractures. In a study by Bergen et al, the use of modifier-22 for obese patients with acetabular fractures had no impact on reimbursement compared with nonobese patients, despite increased complexity and operative time required for these patients.[23] This suggests coding norms for physician reimbursement are unlikely to motivate clinical behavior. Furthermore, our study demonstrates significant facility risk for discharge disposition, length of stay, and other short-term outcomes for morbidly obese patients which will not be accounted for by current reimbursement or value-based paradigms.

This study has limitations inherent to the use of large databases such as ACS-NSQIP. The CPT code categorization

TABLE 4. Adjusted Cost Comparison Complications Data

Complication	Severe Obesity	Normal BMI (18–30)	OR (95% Confidence Interval)	*P*	Adjusted Cost (USD)	% or Raw Difference Between Cohorts	Weighted Cost difference per Severe Obesity Patient
Prolonged ventilation	12 (1.7)	29 (0.4)	3.75 (1.91–7.38)	<0.001	$48,168	1.3	$626.18
Unplanned intubation	9 (1.2)	56 (0.9)	1.44 (0.71–2.93)	0.202	$26,718	0.3	$80.15
Cardiac event	8 (1.1)	63 (1.0)	1.14 (0.54–2.39)	0.422	$15,109	0.1	$15.11
Renal failure	3 (0.4)	12 (0.2)	2.24 (0.63–7.97)	0.186	$18,528	0.2	$36.51
Pneumonia	23 (3.2)	156 (2.4)	1.33 (0.84–2.08)	0.129	$9401	0.8	$75.22
Readmission	57 (7.9)	344 (5.3)	1.53 (1.14–2.04)	0.004	$15,200	2.6	$395.20
Length of stay	5.8 ± 10.21 d	4.9 d ± 8.2 d	—	<0.001	$2873/d	0.9 d	$2585.70
Operative time	115 min ± 56 min	103 min ± 54 min	—	<0.001	$37/min	12 min	$444.00
Summary cost difference per patient							$4258.07
Cost difference for severe obesity cohort per year 2012–2019							$365,776.431
Cost difference during study period							$3,091,358.82

of injuries limits the ability to correlate fracture classification with the outcomes observed in this study. The ACS-NSQIP study does not track outcomes beyond the short-term 30-day postoperative period; thus, the significance of the findings in this study for long-term patient outcomes are difficult to assess. Many articles have been written on differences across United States databases used in orthopaedic research. The ACS-NSQIP provides granular, relatively comprehensive 30-day outcome data in a large population of patients across diverse geographic regions. However, there are also no functional outcomes or specific patient-centered outcomes such as range of motion, pain, or radiographic outcome available in this database. Furthermore, the ACS-NSQIP database skews toward academic medical centers which have a concentration of highly trained health care professionals. Thus, the findings from this study may underestimate the impact of severe obesity observed in the community setting. Payor status, geographic location, and other patient and hospital demographic factors are also unavailable in ACS-NSQIP; thus, the impact of these findings may not be applicable to all hospital settings or patient populations when stratified by region or socioeconomic status.

The findings from this study contribute to the body of literature demonstrating that severely obese patients undergoing surgical treatment of femoral and tibial shaft fractures are subject to increased operative times and experience a greater number of adverse events, have a higher infection rate, a longer overall length of stay, and a higher readmission rate. These findings suggest that surgeons and hospitals caring for a disproportionate number of obese patients may face an undue cost and capacity burden, especially under bundled payment systems. The higher prevalence of obesity in Black and other minority patients in the United States also has implications for health equity. Although this study did not reveal statistically significantly higher rates of severe obesity in racial and ethnic minorities, population health data have repeatedly shown higher rates of obesity in Black and Hispanic patients. As shifts toward value-based care occur, policy considerations should be made to incentivize care for the severely obese patient population, particularly in trauma where modification of risk factors before surgery is often not feasible.

REFERENCES

1. Hales CM, Carroll MD, Fryar CD, et al. Prevalence of obesity and severe obesity among adults: United States, 2017-2018. *NCHS Data Brief*. 2020;360:1–8.
2. Mihalko WM, Bergin PF, Kelly FB, et al. Obesity, orthopaedics, and outcomes. *J Am Acad Orthop Surg*. 2014;22:683–690.
3. Finkelstein EA, Chen H, Prabhu M, et al. The relationship between obesity and injuries among U.S. adults. *Am J Health Promot*. 2007;21:460–468.
4. Byrnes MC, McDaniel MD, Moore MB, et al. The effect of obesity on outcomes among injured patients. *J Trauma*. 2005;58:232–237.
5. Karunakar MA, Shah SN, Jerabek S. Body mass index as a predictor of complications after operative treatment of acetabular fractures. *J Bone Joint Surg Am*. 2005;87:1498–1502.
6. Porter SE, Russell Gv, Dews RC, et al. Complications of acetabular fracture surgery in morbidly obese patients. *J Orthop Trauma*. 2008;22:589–594.
7. Weinlein JC, Deaderick S, Murphy RF. Morbid obesity increases the risk for systemic complications in patients with femoral shaft fractures. *J Orthop Trauma*. 2015;29:e91–e95.
8. Kempegowda H, Richard R, Borade A, et al. Obesity is associated with high perioperative complications among surgically treated intertrochanteric fracture of the femur. *J Orthop Trauma*. 2017;31:352–357.
9. Childs BR, Nahm NJ, Dolenc AJ, et al. Obesity is associated with more complications and longer hospital stays after orthopaedic trauma. *J Orthop Trauma*. 2015;29:504–509.
10. Burrus MT, Werner BC, Yarboro SR. Obesity is associated with increased postoperative complications after operative management of tibial shaft fractures. *Injury*. 2016;47:465–470.
11. Atanda A, Pelton M, Fabricant PD, et al. Telemedicine utilisation in a paediatric sports medicine practice: decreased cost and wait times with increased satisfaction. *J ISAKOS*. 2018;3:94–97.
12. Mittwede PN, Gibbs CM, Ahn J, et al. Is obesity associated with an increased risk of complications after surgical management of acetabulum and pelvis fractures? A systematic review. *J Am Acad Orthop Surg Glob Res Rev*. 2021;5:e21.00058.
13. Neiman R. Re: knee pain and functional scores after intramedullary nailing of tibial shaft fractures using a suprapatellar approach. *J Orthop Trauma*. 2019;33:e208–e209.
14. Debaun MR, Chen MJ, Bishop JA, et al. Orthopaedic trauma quality measures for value-based health care delivery: a systematic review. *J Orthop Trauma*. 2019;33:104–110.
15. Pioli G, Lauretani F, Pellicciotti F, et al. Modifiable and non-modifiable risk factors affecting walking recovery after hip fracture. *Osteoporos Int*. 2016;27:2009–2016.
16. Sathiyakumar V, Molina CS, Thakore Rv, et al. ASA score as a predictor of 30-day perioperative readmission in patients with orthopaedic trauma injuries: an NSQIP analysis. *J Orthop Trauma*. 2015;29:e127–e132.
17. Hustedt JW, Goltzer O, Bohl DD, et al. Calculating the cost and risk of comorbidities in total joint arthroplasty in the United States. *J Arthroplasty*. 2017;32:355–361.e1.
18. Clavien PA, Barkun J, de Oliveira ML, et al. The clavien-dindo classification of surgical complications: five-year experience. *Ann Surg*. 2009;250:187–196.
19. Agency for Healthcare Research and Quality RM. *Estimating the Additional Hospital Inpatient Cost and Mortality Associated with Selected Hospital-Acquired Conditions*. Available at: https://www.ahrq.gov/hai/pfp/haccost2017.html. Accessed November 6, 2021.
20. Merkow RP, Shan Y, Gupta AR, et al. A comprehensive estimation of the costs of 30-day postoperative complications using actual costs from multiple, diverse hospitals. *Jt Comm J Qual Patient Saf*. 2020;46:558–564.
21. Cairns MA, Moskal PT, Eskildsen SM, et al. Are medicare's "Comprehensive care for joint replacement" bundled payments stratifying risk adequately? *J Arthroplasty*. 2018;33(9):2722–2727.
22. Smith EL, Tybor DJ, Daniell HD, et al. The 22-modifier in reimbursement for orthopedic procedures: hip arthroplasty and obesity are worth the effort. *J Arthroplasty*. 2018;33(7):2047–2049.
23. Bergin PF, Kneip C, Pierce C, et al. Modifier 22 for acetabular fractures in morbidly obese patients: does it affect reimbursement? *Clin Orthop Relat Res*. 2014;472(11):3370-3374.