Archives of Orthopaedic and Trauma Surgery (2023) 143:373–379
https://doi.org/10.1007/s00402-022-04338-z

TRAUMA SURGERY

Patient obesity is associated with severity of proximal humerus fractures, not outcomes

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Received: 23 June 2021 / Accepted: 3 January 2022 / Published online: 20 January 2022

Abstract

Purpose The purpose of this study is to evaluate the effect of obesity on the outcome of operatively treated proximal humerus fractures.

Methods Between December 2003 and October 2020, 240 patients with proximal humerus fractures requiring surgery were prospectively followed and classified according to the international AO/Orthopedic Trauma Association (AO/OTA) and Neer classifications. Patients' body mass indexes (BMI) were calculated and used to identify two groups, BMI ≥ 30 kg/cm (obese) and < 30 kg/cm (non-obese). Independent *t* tests were used for statistical analysis of continuous variables and χ^2 tests for categorical variables. Regression analysis was performed to determine if BMI was a predictor of fracture pattern severity as determined by the AO/OTA classification.

Results Overall, 223 patients who sustained proximal humerus fractures were analyzed. Patient age at time of injury was 60.5 ± 13.7 years. There were 67 AO/OTA 11A, 79 AO/OTA 11B, and 77 AO/OTA 11C fracture types. Seventy-two patients (32.3%) were obese. No significant differences were seen between groups in regard to demographic variables, Neer classification, or functional and clinical outcomes as determined by DASH scores and shoulder ROM, respectively. Statistical analyses confirmed that obesity is associated with more severe fracture patterns of the proximal humerus as categorized by the AO/OTA classification. An independent *t* test confirmed that BMI was significantly higher in the complex fracture group based on the AO/OTA classification ($p = 0.047$). Regression analysis also demonstrated that age ($p = 0.005$) and CCI ($p = 0.021$) were predictors of more severe fractures, while BMI approached significance ($p = 0.055$) based on the AO/OTA classification.

Conclusion A significantly higher incidence of complex proximal humerus fracture patterns is observed in patients with higher body mass indexes based on the AO/OTA classification. Age and CCI are also associated with more severe fracture patterns of the proximal humerus as determined by the AO/OTA classification. No differences were seen in outcomes or complication rates between obese patients and non-obese patients.

Level of evidence Level III.

Keywords Obesity · Proximal humerus fracture · Fracture severity · Outcomes

Introduction

Obesity is an ever-growing epidemic in the United States. As of 2010, as many as 35.5% of adult men and 35.8% adult women in America are obese [1]. The prevalence of obesity in adults has not only increased significantly in the United States but also worldwide. According to the World Health Organization (WHO), worldwide obesity has more than doubled since 1980 with over 600 million adults in 2014 categorized as obese [2]. Defined as a body mass index (BMI) equal to 30 and greater, obesity has been extensively reported in the literature to cause not only medical problems, but musculoskeletal issues as well [3]. Musculoskeletal effects of obesity range from biomechanical to biochemical. There is an association between obesity and development of osteoarthritis via excessive load on weight-bearing joints. Wound healing and bone-healing complications following orthopedic or trauma surgery as well as post-traumatic osteoarthritis have been reported

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and thought to be associated with the biochemical inflammatory state that obesity causes [4, 5].

In regards to fracture risk, obesity has been reported to have a varied effect [6]. Obesity may reduce fracture risk due to increased bone density and more favorable bone geometry via greater mechanical loading on the appendicular skeleton. Obesity is also postulated to decrease fracture risk by causing greater absorption of impact forces by soft tissue padding. Furthermore, studies have also concluded that obesity has a protective effect against fragility fractures of the hip and pelvis [7, 8].

Conversely, it has been reported that obesity increases the risk of trauma by 48%, including minor injuries and fractures [9–11]. This is attributable to increased impact forces (force = mass × acceleration) and energy imparted at the time of trauma ($kE = 1/2\ MV^2$). More specifically, obesity is associated with an increased risk of injury to the upper limbs; obese people are twice as likely to sustain an upper extremity injury compared to non-obese people. Consequently, falling on an outstretched arm can often cause more comminution of upper extremity fractures in obese individuals [12–14].

It is known that management and outcomes of proximal humerus fractures are dependent upon the characteristics of the fracture and the patient, including the complexity of the fracture and comorbidities of the patient [15]. Obesity is a non-modifiable comorbidity that has been demonstrated in the literature to have an impact on outcomes and complication rates following orthopedic surgical management of the upper extremity, including increased risk of infection [16–19]. However, there is a paucity of literature that characterizes the relationship between obesity and complications and functional outcomes after proximal humerus fixation.

Studies have established an association between obesity and more complex fracture patterns of the ankle and distal radius in adults and supracondylar humerus fractures in children [13, 20, 21]. Yet a relationship between obesity and proximal humerus fracture severity in adults has not been previously established. The characterization of this relationship is important as it may have consequences for healthcare costs, patient disability, and patient management. There are also few studies examining the association between obesity and complications following operative management of proximal humerus fractures. The purpose of this study is to evaluate the relationship between patient obesity and proximal humerus fracture pattern severity, complications, and outcomes. The authors hypothesized that obese patients, as determined by BMI, would demonstrate a higher complexity of fracture as compared to non-obese patients. In addition, it was hypothesized that obese patients would have a higher rate of complications as well as poorer clinical and functional outcomes.

Materials and methods

Between December 2003 and October 2020, 240 patients who sustained proximal humerus fractures and were treated operatively with open reduction and internal fixation using locking compression plates were enrolled in an IRB-approved database. All patients underwent initial physical and radiologic examination. Complete data were available for 223 patients who sustained proximal humerus fractures. Patients with a history of pathological fracture, less than 6 months of follow-up or younger than the age of 18 were excluded from the analysis.

Prospectively collected patient-reported functional outcome data were obtained using the Disabilities of Arm, Shoulder, and Hand (DASH) questionnaire and reviewed. All DASH data were collected at 3, 6, and 12 months, and beyond on an annual basis for postoperative follow-up. The examination of patients by an orthopedic surgeon also occurred at these time points and included evaluation of range of motion of the injured shoulder and analysis of radiographs (anteroposterior (AP), lateral, and axillary views). Demographic data and injury characteristics were recorded, including age at the time of injury, gender, weight, height, AO/OTA classification, BMI, Charlson Comorbidity Index (CCI), postoperative complications (such as infection, avascular necrosis, screw penetration, hardware failure, nonunion, neuropathies, and venous thromboembolism), follow-up shoulder ROM (forward elevation and external rotation), and latest follow-up DASH scores.

Injury anteroposterior (AP), axillary, and scapula lateral views radiographs, CT scans if obtained as well as intraoperative findings were used to classify the fractures. Fractures were classified by the attending orthopedic surgeon according to the international AO/Orthopedic Trauma Association (AO/OTA) classification and the Neer classification to determine their severity [22]. All patients underwent surgical repair of their proximal humerus fractures following a standardized treatment algorithm, which was based upon several fractures and patient characteristics, including amount of displacement of the fracture, and the functional status of the patient. All operations were performed under the supervision of a fellowship-trained orthopedic trauma surgeon. For purposes of this study, all type AO/OTA 11A proximal humerus fractures were categorized as less severe and type AO/OTA 11B or 11C were categorized as more severe [13]. Neer 3-part and 4-part fractures were categorized as more severe and Neer 2-part fractures were categorized as less severe.

Patients' body mass indexes (BMI) were calculated by dividing the weight of the patient (in kgs) by the height (square meters). After calculation, the BMI was used to classify patients into one of two groups: a non-obese group and an obese group. World Health Organization BMI classifications of underweight (BMI < 18.5), normal weight (BMI = 18.5–24.9), and overweight (BMI = 25.0–29.9) were all included in the non-obese group. BMIs equal to or greater than 30 were considered obese and were included in the obese group [23].

Univariate analysis yielded descriptive statistics for the variables. Bivariate comparisons between the obese group and non-obese groups were conducted along with an independent *t* test for analysis of continuous variables and the Chi-squared analysis for categorical variables. Multivariate analysis was performed to determine the role BMI played in predicting fracture pattern severity as determined by AO/OTA classification, controlling for potential confounders. Significance was defined as $p < 0.05$.

Table 1 Demographics of the obese and non-obese cohorts

	Obese ($n = 72$)	Non-obese ($n = 151$)	*p* value
Age (years)	59.4 ± 13.1	61.0 ± 14.0	0.440
Gender (% female)	66.7%	70.9%	0.525
Height (inches)	64.8 ± 4.4	65.5 ± 3.9	0.204
CCI	2.1 ± 1.9	2.3 ± 2.1	0.650
AO/OTA classification			
11A	16 (22.2%)	51 (33.8%)	0.078
11B	27 (37.5%)	52 (34.4%)	0.655
11C	29 (40.3%)	48 (31.8%)	0.212
Neer classification			
2	15 (20.8%)	49 (32.5%)	0.073
3	38 (52.8%)	77 (51.0%)	0.803
4	19 (26.4%)	25 (16.6%)	0.085

Results

Overall, 223 patients who sustained proximal humerus fractures with a mean follow-up time for of 19.3 ± 16.8 months qualified for analysis. The average age at time of injury was 60.5 ± 13.7 years (range 21–89) and the cohort consisted of 155 (69.5%) women and 68 (30.5%) men. The mean BMI for the entire cohort was 28.4 ± 7.1 (range 15.1–53.3). The mean forward elevation (FE) and external rotation (ER) for the entire cohort was 146.8 ± 26.9 degrees and 48.2 ± 17.5 degrees, respectively. The average DASH score was 21.1 ± 21.2 while the average CCI for the cohort was 2.2 ± 2.0.

Overall, a total of 38 patients (17.0%) experienced 45 complications. This included 4 fracture nonunions, 8 postoperative infections, 15 screw penetrations, 13 patients who developed avascular necrosis, 3 hardware failures, 1 postop pulmonary embolus, and 1 peri-implant fracture. Demographic characteristics between the cohorts are summarized in Table 1.

No differences existed between BMI groups with regard to demographics such as: age ($p = 0.440$), gender ($p = 0.525$), height ($p = 0.204$) or CCI ($p = 0.650$). No differences between groups were identified based on outcomes such as: DASH scores ($p = 0.815$), forward elevation ($p = 0.431$), external rotation ($p = 0.336$) and complication rates ($p = 0.781$). A subset analysis analyzing infection alone as a complication yielded no statistical difference between the groups ($p = 0.442$) (Table 2).

A subset analysis of the obese group was performed comparing obese patients (30.0–39.9) with morbidly obese (BMI > 40) patients (Table 3). As might be expected, a significant difference was confirmed in CCI; the obese group had a mean CCI of 1.8 ± 1.9 whereas the morbidly obese group had a mean CCI of 3.0 ± 1.4 ($p = 0.005$).

Comparison of AO/OTA fracture classifications revealed that BMI was significantly higher in patients with severe fracture patterns (29.0 ± 7.3 vs. 27.0 ± 6.4, $p = 0.047$) (Table 4). A binomial logistic regression further investigated the effects of age, gender, BMI, and CCI on the likelihood of patients having more severe fracture patterns based on the AO/OTA fracture classification (Table 5). Binary logistic regression indicated that age ($p = 0.005$) and CCI (0.021) are significant predictors of fracture severity. BMI approached significance as a predictor of severe fracture patterns ($p = 0.055$). The binary logistic model correctly predicted 95.5% of AO/OTA severe fracture cases and 10.4% of non-severe fracture cases, giving an overall percentage correct prediction rate of 70%.

Discussion

The present study demonstrates that a significantly higher proportion of complex proximal humerus fractures are observed in patients with higher body mass indexes based on AO/OTA classification. Age and CCI are also both associated with more severe fracture patterns according to this classification. Despite the association between increasing BMI and increasing fracture pattern severity as indicated by the AO/OTA classification, data analysis demonstrates that obesity does not result in higher postoperative complication rates and poorer functional and clinical outcomes when compared to non-obese patients undergoing proximal humerus fracture fixation with locking compression plates. The implication of these results is key; it provides evidence that obesity itself is not a disqualifying factor when considering shoulder fracture repair. Orthopedic surgeons should continue to perform proximal humerus fixation on obese patients without concern for higher risks of complications and poorer outcomes.

Table 2 Clinical outcomes of the normal and obese BMI groups

	Obese ($n = 72$)	Non-obese ($n = 151$)	p value
Latest DASH	21.6 ± 21.4	20.9 ± 21.2	0.815
Forward elevation (degrees)	148.9 ± 24.24	145.7 ± 28.1	0.431
External rotation (degrees)	49.9 ± 16.0	47.3 ± 18.2	0.336
Follow-up (months)	19.5 ± 18.3	19.2 ± 16.1	0.899
Complications	19.4%	19.2%	0.781
Infection	1.4%	4.6%	0.442

Table 3 Summary of statistical analyses between obese and morbidly obese groups

	Obese ($n = 52$)	Morbid obesity ($n = 19$)	p value
Age (years)	59.3. ± 14.1	59.7 ± 10.3	0.890
Gender (% female)	36.5%	21.1%	0.217
Height (inches)	65.3 ± 4.2	63.4 ± 4.8	0.093
CCI	1.8 ± 1.9	3.0 ± 1.4	0.005*
AO/OTA classification			
11A	12 (23.1%)	4 (21.1%)	1.000
11B	18 (34.6%)	8 (42.1%)	0.562
11C	22 (42.3%)	7 (36.8%)	0.678
Neer classification			
2	10 (19.2%)	4 (21.1%)	1.000
3	29 (55.8%)	9 (47.4%)	0.530
4	13 (25.0%)	6 (31.6%)	0.579
DASH (latest)	21.2 ± 21.5	22.0 ± 21.9	0.889
Forward elevation (degrees)	151.1 ± 24.1	141.3 ± 24.7	0.176
External rotation (degrees)	51.9 ± 16.2	44.0 ± 14.4	0.097
Follow-up (months)	15.6 ± 8.7	31.5 ± 31.3	0.055
Complications	19.2%	21.1%	1.000

*Significance of $p < 0.05$

Table 4 Comparison of non-severe (11A) versus severe (11B, 11C) OTA/AO fracture patterns

	Non-severe ($n = 67$)	Severe ($n = 156$)	p value
Age (years)	62.8 ± 12.8	59.5 ± 14.0	0.104
Gender (% female)	65.7%	71.2%	0.415
CCI	2.0 ± 2.0	2.4 ± 2.1	0.190
BMI	27.0 ± 6.4	29.0 ± 7.3	0.047*
Latest DASH	20.4 ± 22.3	21.5 ± 20.8	0.748
Forward elevation (degrees)	148.3 ± 26.4	146.1 ± 27.1	0.594
External rotation (degrees)	50.4 ± 18.0	47.2 ± 17.3	0.241
Follow-up (months)	19.7 ± 23.2	19.0 ± 13.0	0.783
Complications	19.4%	19.2%	0.976

Previous studies have reported interobserver reliability variability with the Neer classification [24], as well as the arbitrary definition of fracture displacement and ability to measure displacement on two-dimensional radiographs [25]. Therefore, the AO/OTA classification system may be a more useful tool for proximal humerus fracture classification. Furthermore, Fischer et al. [26] found that fracture severity based on the Neer and AO/OTA classification system does not predict outcomes of proximal humerus fractures.

Regression analysis included the following variables: age, gender, CCI, and BMI. Age was included because it is known that although proximal humerus fractures exhibit a bimodal distribution, it is a common fragility fracture in the elderly. Gender was included because proximal humerus

Table 5 Logistic regression predicting the likelihood of severe fracture based on age, gender, CCI, and BMI

	B	SE	Wald	*df*	*p*	Odds ratio	95% CI for EXP(*B*)	
							Lower	Upper
Age	− 0.038	0.014	7.846	1	0.005*	0.962	0.937	0.989
Gender	− 0.507	0.341	2.215	1	0.137	0.602	0.309	1.174
CCI	0.195	0.084	5.341	1	0.021*	1.216	1.030	1.435
BMI	0.046	0.024	3.696	1	0.055	1.047	0.999	1.097
Constant	1.660	1.029	2.602	1	0.107	5.261		

Gender is for males compared to females

*Significance of $p < 0.05$

fractures occur in more frequently in women, particularly because women exhibit an increased prevalence of osteoporosis. This analysis demonstrated that gender had no effect on severity. Lastly, this study determined that medial comorbidities as measured by the CCI had an effect on fracture severity, likely because obesity is associated with many medical comorbidities that can further complicate orthopedic injuries. The model was significant due to the ability of age and CCI to predict severity of proximal humerus fractures, and the ability of BMI to predict severity of fractures approached significance.

Some literature has suggested that obesity has a beneficial effect by decreasing fracture risk. More mass leads to greater mechanical loading with movement, stimulating bone formation via the Wnt/β-catenin pathway [8, 27, 28]. However, the upper extremities are not exposed to the same mechanical loads as the lower extremities. Consequently, this mechanism of bone density maintenance is not present in the upper extremities. This protective effect is not seen in the proximal humerus in a majority of patients and, in turn, can leave this area more susceptible to more severe fracture in obese patients. This explains the observed significant incidence of severe fracture patterns in the obese cohort.

Obesity has also been proven to have a detrimental effect on fracture risk at a cellular level, elevating the risk for complex fracture [29]. Osteoblasts and adipocytes come from the same progenitor cell and obesity increases the formation of adipocytes at the expense of osteoblastogenesis [30]. Obesity also causes a general chronic inflammatory state, increasing inflammatory cytokines such as interleukin-6 and tumor necrosis factor-α that stimulate osteoclastic activity via the RANK ligand/osteoprotegerin pathway [31]. This information provides more support for the observed result in the obese cohort.

A number of clinical studies have also demonstrated that obesity has a detrimental effect on the musculoskeletal system, particularly in the realm of fracture severity. Spaine and Bollen found that patients with displaced malleolar fractures had a significantly higher BMI than those with nondisplaced malleolar fractures (28.25 vs. 24.58; $p = 0.0001$) [21]. King et al. used the Weber ankle fracture classification to classify ankle fractures into severity groups, considering Weber C fractures as more severe injuries. This study concluded that obese patients were almost twice as likely to sustain Weber C (more severe) ankle fractures than their non-obese counterparts [32]. To date similar studies in the shoulder have not been performed until now.

In a cohort of 423 adult subjects, Ebinger et al. investigated the relationship between obesity and distal radius fracture severity after low-energy trauma. Similar to the current study, Ebinger et al. classified severity by AO/OTA classification. After comparisons between severity groups, the study found that BMI was significantly higher in the complex fracture group as compared to the simple fracture group (28.71 ± 7.19 versus 27.36 ± 6.51, $p = 0.043$). This finding was similar between fracture severity groups in this study. Regression analysis for Ebinger et al. demonstrated that age > 50, gender, and obesity were independent risk factors for sustaining a complex injury pattern [13]. Similarly, regression analysis in this study confirmed that age and CCI were significant predictors of proximal humerus fracture severity and BMI approached significance.

A retrospective administrative database cohort study by Werner et al. examining the effect of obesity on postoperative complications found that obesity was associated with increased postoperative complications after operative fixation of proximal humerus fractures. The study found that obese fracture repair patients had an increased risk of 90-day local complications (including postoperative stiffness and postoperative infection) as well as systemic complications (such as pulmonary embolism, deep-vein thrombosis, myocardial infarction, respiratory failure, cerebrovascular accident, renal failure, and urinary tract infection) [19]. These findings are divergent from the findings of the current study as the present study revealed no differences in complication rates between obese and non-obese populations. However, unlike Werner et al. which examined complication rates within 90 days, the complications recorded in the present study are more granular and were recorded until latest follow-up visit (mean follow-up length: 19.3 months) as opposed to being the result of medical coders identifying issues. It is possible that if Werner et al. recorded complications for a longer period of time, the resultant complication rates between groups would have been different. A contrary result to that of Werner et al. was reported by Griffin et al. In this study, obesity was not associated with an increased incidence of most postoperative complications following shoulder arthroplasty [16].

There are limitations to the current study. It is possible that with the use of the AO/OTA classification system and the known reliability limitations that comes with it, a fracture may have been misclassified. Furthermore, all patients analyzed in this study underwent proximal humerus fixation. Therefore, the cohort may have inherently included more severe fractures and may not be uniformly representative of the population of proximal humerus fractures at large. It is important to note that in this study, there was no difference in CCI between obesity groups. It was only a predictor of severe fractures in the study's cohort. Obesity is known to be associated with various medical comorbidities, including hypertension, diabetes, and cardiovascular disease. It is possible that we did not have a representative population of obese patients, since the obese group did not exhibit higher rates of comorbidities compared to the non-obese group. This was further explored in a comparison of obese versus morbidly obese patients where no significant differences were demonstrated between the groups as demonstrated in Table 3. However, this can also be considered a strength of the present study because it clearly delineates obesity's effect on fracture severity without confounding factors such as medical comorbidities.

To date, there has been no study directly comparing obese and non-obese patients following proximal humerus fracture to determine whether obesity predisposes increased severity of fractures after injury, complications, and worse long-term functional and clinical outcomes. With increasing rates of obesity, this relationship may have important epidemiological implications in the future, particularly in the ability to predict proximal humerus fracture burden and severity in society via BMI. In addition, these results should provide reassurance to orthopedic surgeons that preforming proximal humerus fixation in obese patients can yield equivalent functional and clinical outcomes for non-obese patients.

Conclusion

In conclusion, obesity is associated with more severe fracture patterns of the proximal humerus that undergo repair as determined by the AO/OTA classification. Age and CCI are also associated with more severe fracture patterns of the proximal humerus. Despite this, there were no differences in outcomes or complication rates between obese patients and non-obese patients. With increasing rates of obesity, this relationship may have important epidemiological implications in the future, including predicting proximal humerus fracture burden and severity in society. Orthopedic surgeons can be reassured that performing proximal humerus fixation in obese patients yields similar outcomes and complication rates to non-obese patients. Thus, patient obesity should not factor into decision making when considering operative treatment for a proximal humerus fracture that meets indications.

Funding There was no source of funding for this study.

Code availability Not applicable.

Declarations

Conflict of interest Kenneth A. Egol, MD is a committee member of the Orthopaedic Trauma Association, a paid consultant for and Surgeon-designer for Exactech, a paid speaker for Smith & Nephew, and receives research support or publishing royalties from Acumed, Synthes, SLACK Incorporated, and Wolters Kluwer. The remaining authors declare no conflicts of interest.

Ethics approval This study was approved by the NYU School of Medicine Institutional Review Board.

Informed consent Informed consent was obtained from all individual participants included in the study.

Consent for publication All necessary consents were obtained.

Data transparency All data presented complies with journal standards. Upon request, the authors are prepared to send relevant documentation or data to verify the validity of the results presented.

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