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The Relationship Between BMI and Stability of Intertrochanteric Fracture Following Low-Energy Falls. A Retrospective Cohort Study

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Abstract

Introduction: Intertrochanteric proximal femur fractures are common injuries in the elderly. Certain patterns are considered unstable and confer increased risks. Risk factors for these patterns are not well defined. We sought to determine whether increased body mass index (BMI) was associated with increased risk of sustaining an unstable pattern intertrochanteric (IT) fracture following low-energy trauma. **Materials and methods**: Retrospective case review of all patients presenting to a level-2 trauma center between October 2010 and August 2014 with Intertrochanteric fracture. Fracture pattern (stable or unstable) and BMI were analyzed using odds ratios and age was controlled for. **Results:** Four hundred fifty-two patients were identified. No difference was found between fracture stability when BMI of 25 was used as a cutoff. However, when a BMI of 30 was used as a cutoff, there was a trend of difference (relative difference 30%) in rates of fracture type favoring unstable patterns in the obese group. This difference approached but did not reach statistical significance ($P = .08$). When adjusted for age, the difference remained but still did not reach statistical significance ($P = .11$). **Discussion:** Unstable type IT fractures were found more frequently in the obese cohort (BMI >30) than those who were not obese.

Keywords

fragility fractures, geriatric trauma, metabolic bone disorders, osteoporosis, trauma surgery

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Introduction

Hip fracture in the elderly is a common injury and the incidence is increasing. Each year, 1.6 million hip fractures are estimated to occur worldwide, and this number is projected to reach 2.5 million by 2050.[1] A hip fracture confers significant morbidity and mortality as well as a high economic burden.[2,3] Approximately half of all hip fractures are classified as intertrochanteric (IT) fractures.[4] Certain patterns of IT fractures are considered inherently unstable.

These patterns are reverse obliquity, loss of posterior medial buttress, lateral wall comminution, and subtrochanteric extension.[5] These difficult patterns are associated with longer operative time, increased need for open reduction, higher postoperative mortality, hardware failure, head cutout, and varus malunion.[6,7] It is well defined that low energy hip fractures in the elderly occur as a result of a sideways fall from standing and direct impact on the greater trochanter.[8,9] However, risk factors leading to more unstable patterns after a low-energy mechanism are not defined.

The World Health Organization defines obesity as abnormal or excessive fat accumulation that presents a risk for health. Body weight is classified by body mass index (BMI). A BMI greater than 30 kg/m^2 is obese, a BMI of 25 to 29.9 kg/m^2 is overweight, and a BMI less than 18.5 kg/m^2 is underweight.[10] Given that force is equal to mass multiplied by velocity squared, we postulated that greater patient weight could result in more unstable fracture patterns resulting from low-energy

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falls. In this study, we sought to determine whether there is a relationship between patients' BMI and occurrence of unstable type IT femur fractures resulting from low-energy mechanisms. We hypothesized that increased BMI would increase the likelihood of sustaining an unstable fracture pattern.

Materials and Methods

After IRB approval, we conducted a retrospective chart review of patients with IT fractures presenting to a single community based a level 2 trauma center between October of 2010 and August of 2014. Patients were identified utilizing *ICD-9* codes for IT femur fracture (820.20).

Inclusion and Exclusion Criteria

Inclusion criteria included patients' age ≥18 years, who presented with a fracture occurring between October of 2010 and August of 2014. The diagnosis was made by *ICD-9* code of IT hip fracture, anterior posterior (AP) and cross table lateral radiographs of the affected extremity on presentation, and low-energy mechanism. Exclusion criteria included patients with polytrauma, high-energy mechanisms, periprosthetic fractures, pathologic fractures (not including osteoporotic fractures as pathologic), open fractures, and incomplete demographic data or radiographs.

Demographics

Demographics were obtained by chart review using the institution's electronic medical record system. Patient's date of birth, weight (kg), height (cm), BMI, and mechanism of injury were all recorded. Mechanism of injury was classified into high or low energy. Low energy was defined as a fall from standing height or lower (ie, fall from commode, chair, and bed were all considered low-energy mechanism). High energy was defined as anything else.

Radiographic Analysis

Radiographs were reviewed by 2 orthopedic residents utilizing the institutions picture archive and communication system. All injury films from the encounter were reviewed including AP pelvis, AP and cross table lateral views of hip, or femur. If a manual traction view, CT scan, or MRI were obtained these were also reviewed.

Fractures were classified as either having a stable pattern or an unstable pattern. Stable pattern was defined as normal obliquity fracture without subtrochanteric extension. Pattern was classified as unstable if it was a reverse obliquity pattern or demonstrated significant Subtrochanteric extension. Subtrochanteric extension was defined as any fracture line extending 2 cm below the lesser trochanter to 5 cm below the lesser trochanter. Extension of 2 cm was chosen rather than the most common definition of 1 cm below the lesser trochanter to avoid inadvertently including lesser trochanteric fragments with small distal spikes[11] (Figure 1). The subtrochanteric extension category included patterns with very large lesser trochanter fragments which extended distally conferring instability due to loss of posterior medial buttress. Any uncertainty regarding fracture type was resolved by conference between the 2 authors.

Figure 1. Example of intertrochanteric hip fracture with subtrochanteric extension medially.

Data Analysis

Data was recorded in Research electronic data capture (RedCap), a secure web based data collection and storage tool. Data analysis was performed by the institutions research department using SPSS version 18 statistical analysis software. Pre hoc power calculation was performed prior to data collection. We hypothesized that obesity would have a relative 25% effect size difference in fracture type. This effect size, with a 500 person sample size, provides for power of >90% to detect differences as significant at $P = .05$. Odds ratios were calculated between groups with BMI ≥25 and <25 and statistical significance was estimated using Pearson χ^2 test. The *P* value was set to <.05. This was repeated between groups with BMI <30 and ≥30. Patient's age was then adjusted for using logistic regression and a post hoc power analysis was performed.

Results

A total of 500 patients were identified with *ICD-9* codes for IT fracture during the study period. Of the 500 patients, 2 were excluded due to incomplete demographic data. Six more were excluded because they were coded incorrectly and did not have an IT fracture, resulting in 492 patients, of which 39 were the result of high-energy trauma and were also excluded. This left 453 patients who sustained an IT hip fracture resulting from a low-energy injury who were eligible for data analysis. Of these, 352 (78%) patients sustained a stable type pattern and 101 (22%) patients sustained an unstable pattern, either reverse obliquity or subtrochanteric extension.

Additionally, 283 patients had a BMI <25 (underweight or normal weight). In the BMI <25 group 79% (223 patients) had

Table 1. Number and Type of Fracture Sustained for Body Mass Index (BMI) Groups <25 and >25.

BMI	Total Patients	Patients With Stable Fracture	Patients With Unstable Fracture
<25	283	223 (79%)	60 (21%)
≥25	168	128 (76%)	40 (24%)

Table 2. Number and Type of Fracture Sustained for Body Mass Index (BMI) Groups <30 and >30.

BMI	Total Patients	Patients With Stable Fracture	Patients With Unstable Fracture
<30	395	312 (79%)	83 (21%)
≥30	58	40 (69%)	18 (31%)

a stable fracture pattern and 21% (60 patients) had unstable pattern. Finally, 168 patients had a BMI ≥25 (overweight or obese), 76% (128 patients) had a stable fracture pattern and 24% (40 patients) had unstable fracture patterns (Table 1). Odds ratio between these 2 BMI groups was 1.18 (95% confidence interval [CI]: 0.75-1.86, P = .47). This indicates no statistically significant association between BMI ≥25 unstable IT fracture, when compared to patients with a BMI <25. After adjusting for age, there was still no association between a BMI ≥25 and unstable IT fracture (P = .55).

Patients were then separated into BMI groups ≥30 (obese) and <30 (underweight, overweight, and normal weight). The group with a BMI <30 contained 395 patients (87%). In this group, 79% (312 patients) sustained stable fractures and 21% (83 patients) sustained unstable fractures. The obese group with a BMI ≥30 contained 58 patients (13% of total). In this group, 69% (40 patients) had stable type fractures and 31% (18 patients) had unstable fractures (Table 2). Odds ratio was calculated for fracture type and BMI with a cutoff of 30 and found to be 1.69 (95% CI: 0.92-3.1, P = .09). This indicates a trend of difference (relative difference 30%) in rates of fracture type between BMI groups with a cutoff of 30. This difference approached but did not reach statistical significance (P = .08). When adjusted for age, the difference remained, although not statistically significant (P = .11). A post hoc power calculation determined power to be 60%.

Discussion

There is paucity of literature on the causes and risk factors for type of IT fracture sustained after a low energy fall. We sought to determine whether there is an association between patient's BMI and stability of IT fracture. To our knowledge, this is the only study focusing specifically on patient BMI in relationship to type of IT fracture. We found no difference in rates of unstable fractures between groups when BMI of 25 was used as a cutoff. However, when the obese cohort (BMI ≥30) was compared to nonobese individuals, we found a substantial difference in the number of unstable fractures. The nonobese group (BMI<30) had an unstable pattern 21% of the time compared to 31% of the time in the obese group (BMI >30). This equates to a relative difference of 30% between the groups. Although this trend did not reach significance in our data analysis, this is likely due to a lack of power. Subtrochanteric extension and reverse obliquity fractures are uncommon, yielding only 18 patients in the obese cohort with unstable fracture patterns. This led to a large differential in group sizes, and consequently, our study was underpowered at 60%. However, given the 30% relative difference between nonobese and obese patients who sustained an unstable pattern, it is likely that a larger study would have found a statistically significant difference between these groups.

Similar studies have found equivocal results regarding BMI and stability of IT fractures. However, these studies lack participants with a BMI 30. Given that the trend we observed was only noted in the obese cohort, lack of participants with BMI ≥30 could explain why other studies did not demonstrate the same trend. An observational study performed in Taiwan compared age, gender, BMI, body weight, and height in relation to type of IT fracture. In concordance with our results, they found a slightly higher BMI in the unstable fracture group (BMI of 22.7 vs 21.4) in their univariate analysis. After multivariant analysis, this trend was not observed. However, the mean BMI for their unstable fracture group was 22.7 with a standard deviation of 2.9, indicating that possibly none of the participants had BMI ≥30.[12] Another prospective cohort study by Cauley et al demonstrated that lower bone mineral density (BMD), Parkinson, and slower walking speed are risk factors for sustaining unstable pattern IT fracture after a fall from standing. Yet once again, the average BMI of their unstable fracture group was 26.6 suggesting that the truly obese cohort may have been underrepresented.[13] Without clear evidence on the cause of unstable type IT fractures, we theorize that there must be some alteration in the normal patient or circumstances of impact when a hip fracture occurs. Cummings and Nevit hypothesized that 4 conditions are met to result in a hip fracture in a low-energy fall from standing: (1) fall sideways, (2) loss of protective response, (3) local soft tissue absorbs less energy then what is necessary to prevent facture, and (4) residual fall energy after dispersion by soft tissue must exceed the proximal femur strength.[14] One can extrapolate these principals to assume that one or more of these variables are altered resulting in a stable versus unstable IT fracture. The BMI has an effect on many of these factors particularly proximal femoral strength, residual force of impact, and amount of soft tissue available to disperse forces.

Type of obesity may play an important role in the risk of hip fracture and stability of IT fracture due to its impact on peritrochanteric fat. Two predominant types of obesity have been described. Android obesity, which is more common in men, consists of primarily abdominal and thoracic distributions of adipose tissue. The second type is gynecoid type obesity where adipose tissue is found primarily in the hip and thigh region.[15] While obesity in general is protective against hip fracture, android obesity confers an increased risk of fracture independently of BMD.[16] A recent meta-analysis found a significant increase in the risk of hip fracture in individuals with android-type obesity. Specifically, individuals with a waist circumference of $\geq$105 cm had a 55% increased risk of hip fracture when compared with individuals with waist circumference of <80 cm.[17]

Increased risk of hip fracture is not surprising in android obesity as these individuals would have disproportionally low BMD and larger impact force but lack the increased peri-trochanteric soft tissue cushion. Additionally, this is supported by the efficacy of hip protectors in preventing hip fractures in elderly patients. Hip protectors are foam or plastic pads fitted into specialize underwear and are designed to lie over the trochanteric area. A 2014 Cochrane review including 19 studies found that wearing hip protectors likely decreased the risk of hip fracture in older people in nursing care.[18] To date, no study has examined the relationship between stability of IT fracture and obesity pattern, but type of obesity could possibly contribute to the trend of unstable fractures in our obese cohort.

In addition to increased peri-trochanteric cushion, obesity is protective against hip fracture by its positive effect on BMD.[19] This is primarily mediated by an adaptive increase in BMD in response to higher daily loads (Wolff law).[20-22] Expanding on this concept Beck at al utilized the Women's Health Initiative Observational Cohort to define how obesity affects cross-sectional area and bending strength in addition to BMD in the proximal femur in 4642 Caucasian females. In agreement with prior literature, they found that higher BMI conferred an increased BMD, cross sectional area, and bending strength of the proximal femur. Interestingly, this increase in femoral strength was only proportionate to increase in lean body mass, not total body mass or fat. Simply put, in the most obese cohort, an increase in proximal femoral strength is disproportionately small compared to increase in total body weight as most of the weight is fat rather than lean mass.[23] Another large cross-sectional study by Kim et al looking at peri-menopausal Korean women similarly found BMD to be positively correlated with lean mass and negatively correlated with waist-to-hip ratio (a surrogate for adipose tissue).[24] This would suggest that the most obese cohort would be at increased risk of fracture given their large increase in mass and disproportionately small increase in femur strength. However, this was not demonstrated to be true in observational studies.[15,16,18,23] This is possibly due to the type of obesity and excess adipose tissue about the greater trochanteric region in gynoid type acting as a cushion to disperse forces during a fall.[14] A 2009 cadaveric study found a 1.8-fold increased risk of hip fracture for each standard deviation decrease in peri-trochanteric soft tissue thickness.[25] Similar findings were reported in a case cohort study evaluating dual energy X-ray absorptiometry scan visualized peri-trochanteric soft tissue in 167 patients with hip fracture and fracture risk. This study demonstrated decreased peri-trochanteric fat thickness to be a strong predictor of hip fracture risk after controlling for age, race, clinical site, BMI, chronic disease, hip BMD, self-reported health, alcohol use, smoking status, education, physical activity, and cognitive function.[26] These findings can help explain why obese individuals tend to have lower hip fracture rates despite higher force of impact.

Our study had numerous limitations, first of which is the retrospective nature of the study. Additionally, we were unable to control for multiple possible cofounders including patient comorbidities, prior treatment of osteoporosis, and gender. Also, we did not account for the type of obesity (android or gynecoid), which could have had an influence on force of impact and risk of hip fracture. Additionally, our study was underpowered at 60%, which may be due to the rarity of reverse obliquity and subtrochanteric extension. This resulted in a large differential in group size and consequently low power. Finally, we were unable to control for the type of obesity which may play a key role in force distribution during falls.

Our study did have strengths as well. First of all, it was a relatively large study consisting of over 400 patients. We were able to control for patient age as a cofounder. Additionally, all radiographic data was individually reviewed by an orthopedic resident experienced in evaluating in musculoskeletal radiographs.

Conclusion

The causes and risks of unstable IT fractures are complex and not well defined. We performed a retrospective case–control study based on the hypothesis that obese individuals have higher impact forces during falls from standing and that this could result in more unstable IT fracture patterns. We found a trend toward a difference (relative difference 30%) favoring unstable fractures as more likely in the obese cohort when BMI of >30 was used as a cutoff point. This trended toward statistical significance. This seems to dispute the fact that obesity is generally protective against hip fracture but could be explained by soft tissue distribution patterns, specifically android type obesity lacking peri-trochanteric fat accumulation; more research on this topic is necessary, particularly larger studies in order to overcome the rarity of certain IT fracture patterns.

Declaration of Conflicting Interests

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