RESEARCH ARTICLE

# Impact of Bone Mineral Density Measured by Quantitative Ultrasound of the Heel and Vitamin D Levels on Hip Fracture Patients Aged 55 or Greater: An Analysis of 1,030 Patients

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## Abstract

**Background:** A better understanding of how bone mineral density and vitamin D levels are associated with femoral neck and intertrochanteric hip fractures may help inform healthcare providers. We asked: 1) In patients age ≥ 55 years, is there a difference in quantitative ultrasound of the heel (QUS) t-score between patients with fractures of the femoral neck and those with fractures of the intertrochanteric region, accounting for other factors 2) In patients age ≥ 55 years, is there a difference in vitamin D level between those with fractures of the femoral neck and those with fractures of the intertrochanteric region, accounting for other factors? 3) Is there an association between vitamin D level and QUS t-score?

**Methods:** In this retrospective cohort study, 1,030 patients were identified using CPT codes for fixation of hip fractures between December 2010 and September 2013. Patients ≥ 55 years of age who underwent operative management for a hip fracture following a fall from standing height were included. Three orthopaedic surgeons categorized fracture type using patient radiographs. Upon hospital admission, QUS t-scores and vitamin D levels were determined. Descriptive statistics, bivariate analyses and multivariable regression were performed.

**Results:** Accounting for potential confounders, patients with lower QUS t-scores were more likely to have intertrochanteric femur fractures than femoral neck fractures. In a bivariate analysis, there was no association between vitamin D level and either fracture type. Given the *P-value*, a multivariable analysis was not completed. There was no association between vitamin D level and bone mineral density.

**Conclusion:** Patients with lower bone density that suffer a hip fracture are more likely to suffer a fracture in the intertrochanteric region than the femoral neck, but vitamin D levels are unrelated. Awareness of this association emphasizes the importance of bone mineral density screening to assist with intertrochanteric hip fracture prevention.

**Keywords:** Bone mineral density, Geriatric, Hip fracture, Vitamin D level

## Introduction

Hip fractures are common in the later stages of life and treatment is very costly to the healthcare system (1-3). Additionally, hip fractures are associated with decreased function and independence, fear of falling, greater symptoms of depression, social isolation, and death within a year of fracture (4-6). Hip fractures are expected to increase as people around the world are living longer and healthier lives (2, 7).

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To improve value in the care of hip fractures the United Kingdom implemented national databases to monitor care provided to assure it meets national standards (8).

The Agency for Healthcare Quality & Research (AHRQ) in the United States suggests that there are three major classifications of hip fractures and treatment among them may differ (9). According to the AHRQ, there are different characteristics between two common subtypes of hip fracture - femoral neck and intertrochanteric femur fractures – that are important to understand in order to effectively manage patient cases (9). A better understanding of the factors associated with each fracture subtype might help guide high-value management. In particular the association of fracture type with bone metabolism is of interest.

Quantitative ultrasound of the heel (QUS) is a validated surrogate for the gold standard test of bone mineral density (BMD), a dual-energy x-ray absorptiometry (DXA) (10). DXA is not only expensive but is often unavailable during inpatient admission; however, QUS of the calcaneus is relatively less expensive and accessible to hospital providers.

This study tested the primary null hypothesis that in patients age 55 years or greater, there is no difference in (QUS) t-score between those with fractures of the femoral neck and those with fractures of the intertrochanteric region, accounting for other factors. We also tested the following secondary null hypotheses: 1) in patients age 55 years or greater, there is no difference in vitamin D level between those with fractures of the femoral neck and those with fractures of the intertrochanteric region, accounting for other factors; 2) there is no association between vitamin D level and QUS t-score.

## Materials and Methods

### *Study Design*

An IRB approved, retrospective cohort study at a single urban, community level II trauma center was undertaken. We selected all patients who underwent operative treatment for an isolated fracture of the proximal femur from December 2010 to September 2013, One-thousand thirty patients were identified. Patients were excluded for high energy mechanism (MVC or fall from over 10 feet) and multiple fractures (including fractures of the acetabulum and femur shaft over 5cm distal to the lesser trochanter). Preoperative and postoperative radiographs were obtained from the picture archiving and communication system (PACS) and de-identified. The radiographs were reviewed by the same 3 orthopaedic surgeons (JD, CF, and HS) and a consensus was reached as to fracture type. All fractures were classified based on the AO/OTA fracture classification for proximal femur fractures and grouped as follows: non-displaced and displaced femoral neck fractures; stable, unstable, and reverse obliquity intertrochanteric femur fractures; and subtrochanteric femur fractures. Subtrochanteric femur fractures were omitted from this study.

Upon hospital admission, dedicated Orthopaedic Clinical Nurse Specialists acquired patient demographic information. In addition, patients were tested for serum 25-hydroxy Vitamin D levels and had a QUS of the calcaneus performed upon admission, a routine part of patient care at our institution. The Achilles InSight machine (General Electric Medical Systems) was used to obtain the QUS, which calculates a stiffness index based on the broadband ultrasound attenuation of the midcalcaneus. This is reported as number of standard deviations from the mean, which was calculated using 1000 healthy American people (10). We used a quantitative ultrasound t-score as a surrogate for the dual-energy x-ray absorptiometry (DXA) t-score. A DXA t-score between +1 and -1 is considered normal, between -1 and -2.5 suggests low density, and less than -2.5 indicates osteoporosis (11). As suggested by Collinge, et al a QUS cutoff of greater than -0.9 represents a low risk for osteoporosis and a QUS of -1.6 or less represents a high risks for osteoporosis (10).

The National Institutes of Health (NIH) note that there is an association between patients with Vitamin D levels <12 ng/mL and osteomalacia; in addition, the NIH states that vitamin D levels of 12-19 ng/mL are generally inadequate for bone and overall health, while vitamin D levels ≥ 20 ng/mL is sufficient for bone and overall health (12).

### *Statistical Analysis*

Descriptive statistics were calculated for all patients fitting our inclusion criteria [Table 1]. The results

**Table 1. Patient characteristics**

| Characteristic | Total (n=1,030) |
|---|---|
| Age, mean (SD) | 80 (9.7) |
| Sex, n (%) | |
| Men | 283 (27%) |
| Women | 747 (73%) |
| Race, n (%) | |
| White | 913 (89%) |
| Black | 53 (5.2%) |
| Asian | 3 (0.3%) |
| Other | 61 (5.9%) |
| ASA Classification | |
| 1 | 2 (0.20%) |
| 2 | 153 (16%) |
| 3 | 637 (65%) |
| 4 | 191 (19%) |
| 5 | 3 (0.30%) |
| BMI, mean (SD) (kg/m2) | 24 (5.1) |
| Vitamin D level, mean (SD) | 25 (16) |
| Osteoporosis ultrasound score, mean (SD) | -2.17 (1.2) |

*American Society of Anesthesiologists Physical Classification System
**Body mass index

were summarized with categorical variables being reported as frequency (percentage) and continuous variables as mean (standard deviation). Chi-square and Fisher Exact tests were conducted to test difference between categorical variables and t tests were utilized for continuous variables. Independent variables that had a *P-value<0.10* were included in a multivariable regression. Pseudo-R2 was reported for each independent variable. Additionally, model performance was evaluated using the area under the receiver operating characteristic curve, full model Pseudo-R2 and Hosmer-Lemeshow test.

A post hoc power analysis based on a chi-squared test determined that 1,030 patients provided 99% power to detect a moderate effect (0.30) with an alpha of 0.05.

## Results

In bivariate analysis, patients who had lower QUS t-scores were more likely to have an intertrochanteric than a femoral neck fracture [Table 2]. No other factors were significantly different between fracture types, but the American Society of Anesthesiologists Physical Classification System (ASA) Classification 2 met the criterion (*P<0.10*) to be included in the multivariable regression analysis. In multivariable regression, lower osteoporosis score was the only factor independently associated with intertrochanteric femur fracture (Area under the receiver operating characteristic curve: 0.62; Hosmer-Lemeshow test: *P=0.19*; Pseudo-R2 = 0.028) [Table 3]. Every standard deviation increase in quantitative ultrasound score decreases intertrochanteric femur fracture by 27% relative to femoral neck fracture.

In bivariate analysis, patients with intertrochanteric femur fractures and femoral neck fractures had comparable mean vitamin D levels. A multivariable analysis was not performed.

There was no association between vitamin D levels and quantitative ultrasound scores (*P=0.35*).

**Table 2. Patient characteristics associated with presence of intertrochanteric femur fractures and femoral neck fractures**

| Characteristic | Intertrochanteric Femur Fracture (n=567) | Femoral Neck Fracture (n=463) | *P-Value* |
|---|---|---|---|
| Age, mean (SD) | 80 (9.8) | 80 (9.5) | 0.69 |
| Sex, n (%) | | | |
| Men | 161 (57%) | 122 (43%) | 0.47 |
| Women | 406 (54%) | 341 (46%) | |
| Race, n (%) | | | |
| White | 497 (54%) | 416 (46%) | 0.27 |
| Black | 30 (57%) | 23 (43%) | 0.82 |
| Asian | 1 (33%) | 2 (67%) | 0.59 |
| Other | 39 (64%) | 22 (36%) | 0.15 |
| ASA Classification | | | |
| 1 | 1 (50%) | 1 (50%) | 0.99 |
| 2 | 94 (61%) | 59 (39%) | 0.085 |
| 3 | 353 (55%) | 284 (45%) | 0.76 |
| 4 | 96 (50%) | 95 (50%) | 0.14 |
| 5 | 1 (33%) | 2 (67%) | 0.59 |
| BMI, mean (SD) (kg/m2) | 24 (5.3) | 24 (4.7) | 0.75 |
| Vitamin D level (ng/ml), mean (SD) | 24 (14) | 25 (20) | 0.31 |
| Deficient (<12) | 90 (58%) | 66 (42%) | 0.47 |
| Insufficient (12 ≤ Vitamin D ≤ 20) | 101 (53%) | 88 (47%) | 0.62 |
| Sufficient (> 20) | 376 (55%) | 309 (45%) | 0.89 |
| Osteoporosis ultrasound score, mean (SD) | - 2.4 (1.2) | -1.9 (1.2) | <0.001 |

*American Society of Anesthesiologists Physical Classification System
**Body mass index

**Table 3. Factors independently associated with presence of intertrochanteric fractures in geriatric patients**

| Model: Intertrochanteric fracture characteristics <0.10 in bivariate analysis (logistic regression)* | | | | | |
|---|---|---|---|---|---|
| Area under the receiver operating characteristic curve | 0.62 | | | | |
| Pseudo R2 | 0.028 | | | | |
| Hosmer-Lemeshow test | 0.19 | | | | |
| **Characteristic** | **Odds ratio** | **Lower** | **Upper** | ***P-value*** | **Pseudo R2 (Bivariate)** |
| Osteoporosis ultrasound score | 0.73 | 0.64 | 0.83 | <0.001 | 0.025 |
| ASA Classification 2* | 1.39 | 0.90 | 2.16 | 0.14 | 0.0021 |

*American Society of Anesthesiologists Physical Classification System

## Discussion

Hip fractures are related to osteoporosis and they are more common with older age. The data regarding association of fracture type with bone metabolism is inconsistent. A better understanding of such associations can help educate healthcare providers and be useful in patient counselling.

Our work should be read with it limitations in mind. First, our data was collected at one urban level 2 trauma center. This institution may not be representative of the general population. Second, our data was gathered retrospectively and is subject to human error and miscoding. Third, fracture classification is prone to poor inter-observer reliability. Fourth, because of the technology commonly available in the inpatient setting, we used quantitative ultrasound t-scores of the heel as a surrogate for DXA scan t-scores. Many see the value in heel ultrasound in predicting and screening for osteoporosis, but others emphasize its low positive predictive value (10, 13-16).

We found that patients with lower quantitative ultrasound scores were more likely to have intertrochanteric fractures than femoral neck fractures in both bivariate and multivariable regression analyses. A similar study of 9,704 white women 65 years of age or older with 279 patients having a femoral neck fracture and 222 having an intertrochanteric fracture also found that lower calcaneal bone mineral density is associated with intertrochanteric fracture rather than femoral neck fracture (17). In another study, researchers analyzed the biochemical bone markers and bone mineral density of 106 elderly women with hip fractures (58 intertrochanteric fractures, 48 femoral neck fractures) (18). While the authors found no difference in biochemical markers for bone formation or resorption, they did find that patients with intertrochanteric fractures have more osteoporosis than those with femoral neck fractures (18). In contrast, a study of 49 patients found no associated of fracture type with severity of osteoporosis (19). In our opinion, the weight of evidence suggests that patients with greater osteoporosis are more likely to fracture at the intertrochanteric region than the femoral neck.

Mean vitamin D levels were comparable between femoral neck and intertrochanteric femur fractures. This is consistent with most, but not all of the prior studies. Larrosa et al studied 324 patients over 65 years of age admitted to a hospital in Spain for treatment of an osteoporotic hip fracture over one year (20). The authors found an association between severity of vitamin D deficiency and severity of hip fracture but no association between vitamin D levels and hip fracture types (20). Dretakis et al studied 102 consecutive elderly women with hip fractures who presented to a single hospital in Greece with 53 patients ultimately fitting their inclusion criteria (29 trochanteric fractures, 24 cervical fractures) (21). A control group of 70 patients was also established; they fit the same inclusion criteria except for not having a hip fracture (21). Contrary to our analysis, the authors found patients with trochanteric hip fractures had lower serum vitamin D levels than patients with cervical fractures (i.e., femoral neck fractures) (21). Interestingly, the authors also found that there was no significant difference in patient vitamin D levels between the control and femoral neck fractures (21).

We found no association between vitamin D levels and bone mineral density measured via a quantitative heel ultrasound. Prior research on this is inconsistent: Hosseinpanah et al, in a study of 245 healthy Iranian postmenopausal women found no association between vitamin D levels and bone mineral density (22). In contrast, a study of 13,432 subjects whom had completed the National Health and Nutrition Examination Survey III (NHANES III) between 1988 and 1994 found an association between vitamin D levels and bone mineral density among both young and elderly individuals (23). Further, a study of elderly men found increased vitamin D levels are associated with increased femoral bone mineral density (24). A better understanding of the link between vitamin D levels and bone mineral density would greatly advance efforts to prevent hip fracture.

Patients with lower bone density that fracture their hip are more likely to suffer an intertrochanteric femur fracture then a fracture of the femoral neck. However, vitamin D levels are unrelated. Awareness of this association can help inform the screening and treatment of osteoporosis and hip fracture management protocols. For example, preventative counseling can focus less on Vitamin D supplementation and more on promoting weight-bearing activity to increase bone density. Our findings can also be used by healthcare providers to educate patients on the natural history of osteoporosis, as patients with lower bone mineral density are more likely to require fixation than arthroplasty. Future work should endeavor to build upon our study by analyzing the association of various risk factors, such as the association of lower bone mineral density and worse patient outcomes, accounting for other potential confounders like drug history.

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All other authors (DNB, JTD, CF, KM, HBS) declare they have no conflict of interest.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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