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Factors affecting fracture location in atypical femoral fractures: A cross-sectional study with 147 patients

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ABSTRACT

Introduction: Many studies have tried to determine the characteristics of atypical femoral fractures (AFFs) through age-, sex-, and ethnicity-matched comparison with non-AFFs. However, we hypothesized that diaphyseal AFFs would have characteristics different from those of subtrochanteric AFFs. The aim of this study was to evaluate the clinical features of diaphyseal/subtrochanteric AFFs and determine the factors related to fracture location.

Patients and methods: One hundred forty-seven patients with AFF were enrolled, 114 patients (78%) had a history of bisphosphonate use. Forty-nine patients (33%) had bilateral lesion, and 35% of patients had thigh pain. Patients were divided into two groups according to fracture location: 52 patients (35.4%) with subtrochanteric AFF and 95 patients (64.6%) with diaphyseal AFF. The patient demographics and fracture characteristics of the two groups were compared. Multivariate logistic regression analysis was used to adjust for variables related to fracture location.

Results: The patients in the diaphyseal AFFs group were older and had lower BMI, lower BMD, and larger lateral and anterior bowing. Multivariate analysis revealed that age greater than 65 years and low BMD were related with diaphyseal location. With greater lateral bowing angle, the AFF location was moved from the subtrochanteric area to the diaphyseal area.

Conclusion: This study demonstrated that patients with diaphyseal AFFs had different characteristics compared with those with subtrochanteric AFFs.

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Introduction

Since Odvina et al. [1] described severe suppression of bone turnover after long-term alendronate use in 2005, there has been increasing interest in atypical femoral fracture (AFF), which has been considered as a type of insufficiency fracture associated with long-term use of bisphosphonate (BP). In 2013, the American Society for Bone and Mineral Research (ASBMR) defined AFF, with the major features being location in the subtrochanteric region or femoral shaft, transverse or short oblique orientation, atraumatic or minimal traumatic fractures, medial spike when the fracture is complete, non-comminuted or minimally comminuted, and localized periosteal or endosteal thickening of the lateral cortex [2]. A second report added lower limb geometry and Asian ethnicity as potential contributors to AFF risk. The location of each fracture is likely influenced by the location of stresses and strains in the individual's femur [3]. Asian women have more lateral bowing of the femur compared with whites and African-Americans [4], and diaphyseal AFFs are likely to occur more often than subtrochanteric AFFs in Asians. However, in Singapore, the majority of AFFs appeared to be located in the subtrochanteric area [3,5].

We hypothesized that diaphyseal AFFs would have different features from subtrochanteric AFFs and fracture location would be associated with femoral bowing. Although there have been several reports on the relationship of AFF with femoral bowing [3,6–9],

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there has been no reports sufficiently large number thus far. The aim of this study was to evaluate the clinical features of diaphyseal/subtrochanteric AFFs and determine the factors related to fracture location.

Patients and methods

This is a retrospective cross-sectional study, and the Institutional Review Boards of the participating centers approved this study. We retrospectively reviewed all patients with AFFs, which were defined by the ASBMR in 2013. The exclusion criteria were pathologic fractures with metastasis or metabolic bone disease such as Paget's disease. Data were obtained from seven centers from January 2007 to June 2015, and 147 patients were included in this study. All patients were women, and the average age was 72.9 years (range, 53–96 years), with an average follow-up of 26.2 months. Some patients in one of the seven centers have been reported previously [10].

Patient demographics and characteristics including BMI, BMD, and BP history and its duration were identified from electronic database. Patient interviews were not done. The incidence of bilateral fracture and presence of prodromal symptom were investigated.

Digital Imaging and Communications in Medicine (DICOM) files of plain radiographs of the hip and femur were used for the measurement. Radiologic data were gathered in one center and measured using picture archiving and communication system (PACS) by two orthopedic surgeons, both blinded to all background information. No correction for magnification was performed and complete agreement was achieved between the two readers. We checked the bilaterality of AFFs on initial radiography, but not on sequential follow-up radiography. In cases of complete AFF, we could not acquire the x-ray of the intact femur (pre-injury state); thus, the x-ray of the intact femur on the contralateral side was used to measure the bowing angle, based on the symmetry of human anatomy. Lateral and anterior bowing were measured as the angle formed at the bisection of the two lines drawn through the long axis of the proximal and distal parts of the femur (Fig. 1).

Subtrochanteric fracture was defined as fracture extending up to 5 cm below the lesser trochanter. Diaphyseal femoral fracture was defined as fracture extending from below the subtrochanteric region to the supracondylar metaphyseal flare. Patients were divided into two groups according to fracture location: group 1, with subtrochanteric AFFs, and group 2, with diaphyseal AFFs. The patient demographics and fracture characteristics of the two groups were compared using Fisher's exact test for nonparametric categorical variables and Student's *t*-test for parametric variables. The relationship of lateral and anterior bowing was evaluated using the Pearson correlation coefficient. Multivariate logistic regression analysis was used to adjust for variables related to fracture location. The independent variables were age, BMI, BMD, and lateral and anterior bowing angles. All statistical analyses were performed using PASW Statistics version 18.0 (IBM, Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

Results

The average height of the patients was 152.3 cm; the average weight was 53.0 kg; and the average BMI was 22.8. Forty-nine patients (33%) had bilateral lesion and 35% of the patients had the prodromal sign, thigh pain. One hundred fourteen patients (78%) had history of BP use, and the duration of BP use was, on average, 53.3 months. The most common BP was alendronate (70%), followed by risedronate (15%), ibandronate (7%), zoledronate (1.5%), and pamidronate (1%). The other 5.5% had BP use, but the information of the exact type was not available. BMD data were available in 123 patients (84%), with 7.5% having normal BMD, 36.6% having osteopenia, and 55.8% having osteoporosis. The average T-score was −2.6 (range, 1.3 to −5.7). We acquired the femoral anteroposterior (AP) images of 129 patients (88%) and the lateral images of 101 patients (69%). The lateral bowing angle was $5.6^\circ \pm 5.0^\circ$ (range, -1° to 22°) and anterior bowing angle was $10.2^\circ \pm 4.3^\circ$ (range, 1°–23°). Analysis of 101 patients with both AP and lateral images demonstrated that lateral bowing was correlated with the anterior bowing of the femur ($p < 0.001$) and the Pearson correlation coefficient was 0.511 (Fig. 2).

Fig. 1. Measurement of femoral bowing: (A) lateral and (B) anterior.

Group 1 (those with subtrochanteric AFFs) had 52 patients and group 2 (those with diaphyseal AFFs) had 95 patients (65%). Comparisons between the two groups were summarized in Table 1. The patients in group 1 were older and had lower BMI, lower BMD, and larger lateral and anterior bowing. In the multivariable models, age, BMD, and lateral bowing angle were significantly related to fracture location (Table 2). As the lateral bowing angle was greater, the AFF location was moved from the subtrochanteric area to the diaphyseal area (Fig. 3).

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