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Comparisons of TBS and lumbar spine BMD in the associations with vertebral fractures according to the T-scores: A cross-sectional observation

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ABSTRACT

Trabecular bone score (TBS) is a parameter of bone quality that has been shown to be related to vertebral fractures. This study aimed to analyze the difference in discriminatory power of TBS for vertebral fractures according to the bone mineral density (BMD) T-score. Areal BMD at the lumbar spine (LS, L1–L4), femur neck (FN) and total hip were assessed using dual x-ray absorptiometry (Discovery W, Hologic, Bedford, MA) in 929 women aged 50 years or older. TBS was analyzed using iNsight software (Med-Imaps, Pessac, France). Vertebral fractures were identified on lateral X-ray films of the thoracic and lumbar spine using a semi-quantitative method. The study subjects consisted of 158 subjects (17.0%) with normal BMD, 461 (49.6%) with osteopenia and 310 (33.4%) with osteoporosis. The incident vertebral fractures were observed in 92 (9.9%) subjects, including 59 fractures in osteoporosis, 29 fractures in osteopenia, and only 4 fractures in normal BMD. We stratified study subjects into two groups according to their BMD T-scores, osteoporosis or osteopenia/normal BMD. The logistic regression model showed that LS BMD values per each 1 standard deviation (SD) decrease were significantly associated with increased risk of vertebral fracture in both osteoporosis and osteopenia/normal BMD group with stronger association in osteoporosis group. However, a TBS value that was lower by 1SD was significantly associated with vertebral fracture risk only in the osteopenia/normal BMD group. The TBS use in addition to FN BMD and age also showed significantly better discriminatory power for vertebral fracture only in the osteopenia/normal BMD group, but not osteoporosis group. In conclusion, TBS is significantly associated with vertebral fractures in subjects with osteopenia/normal BMD levels. Additional assessment of bone microarchitecture using TBS is better able to identify women at risk of fracture, in particular, those with relatively higher BMD.

1. Introduction

The incidence of osteoporosis continues to increase with the progressively aging population. Currently, it is estimated to affect 200 million women worldwide: approximately one-tenth of women aged 60, one-fifth of women aged 70, two-fifths of women aged 80 and two-thirds of women aged 90 [1]. Osteoporosis results in fragility fractures that are closely related to loss of quality of life and morbidity, and that can be life threatening in some individuals [2]. Vertebral fracture is the most common type of osteoporotic fracture and is known to be associated with substantial pain, disability, costs, and mortality rates [3]. Moreover, previous vertebral fractures become a risk factor for both subsequent vertebral fractures and nonvertebral fractures [4,5].

Areal bone mineral density measured by dual-energy X-ray absorptiometry (DXA) is accepted as the gold standard for diagnosis of osteoporosis and assessment of fracture risk [6]. However, based on the World Health Organization (WHO) classification threshold for osteoporosis, more than half of incident fractures occur in women who are not osteoporotic but are either osteopenic or have normal BMD [7–9]. Bone strength is determined not only by bone mass but also by bone quality [10]. Therefore, there has been an effort to evaluate bone quality to increase the power to discriminate groups at high risk of fractures beyond that provided by BMD alone. Bone quality is affected by various factors

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including bone turnover, microarchitecture, the degree and distribution of mineralization, and the extent of microdamage and its repair [11]. Several imaging techniques have been developed to assess bone microarchitecture noninvasively such as high-resolution CT and peripheral QCT, and MRI [12–14]. Recently, trabecular bone score (TBS) was introduced as a novel modality to assess trabecular bone quality easily [15]. The TBS is a bone texture analysis derived from the DXA image of the lumbar spine [16,17]. Several reports have shown the predictive values of TBS in evaluating the risks of osteoporotic fracture [18–21]. However, it is not clear which factors affect the predictive value of TBS. Recently, one study reported that TBS could be a significant factor in predicting vertebral fracture, but that the clinical utility of TBS may be somewhat limited among older men with high body mass index or high trunk lean mass [22]. It has also been shown that TBS discriminates better than lumbar spine (LS) BMD for prediction of vertebral fractures in patients with normal or osteopenic BMD, but not in those with osteoporosis [23].

The aim of this study was to analyze the difference in discriminatory power of TBS for vertebral fractures among patients grouped according to the WHO BMD classification compared to those with BMD levels, and also to evaluate the associations between LS BMD and TBS.

2. Patients and methods

2.1. Study participants and design

This was a cross-sectional study including consecutive patients who underwent DXA as screening for osteoporosis at Seoul National University Bundang Hospital (SNUBH, Seongnam, South Korea) between January 2015 and March 2016.

Peri- or postmenopausal women older than 50 years of age were included. Participants were excluded from the analysis if they satisfied any of the following criteria: younger than 50 years old; having taken medications that could affect bone metabolism (e.g., systemic steroids, hormone-replacement therapy, bisphosphonates, calcium or vitamin D replacement); pre-existing medical conditions that could affect bone metabolism (e.g., parathyroid disease, hyper- or hypothyroidism, rheumatoid arthritis, or asthma); solid or hematologic malignancy; or abnormal liver or kidney function. Finally, a total of 929 eligible participants were included in the analyses. The study was approved by the Ethical Review Board of SNUBH (IRB No. B-1510/318–110).

2.2. Bone mineral density

BMD at the lumbar spine, femur neck, and the total hip area were measured by DXA by certified radiological technologists using a single DXA scanner (Discovery W, Hologic, Inc., Bedford, MA, USA) following the manufacturer's protocol. The entire lumbar spine was scanned in posteroanterior projection, and BMD at the lumbar spine was calculated for the first to fourth vertebrae using densitometric software (version 5.5.3, Hologic, Inc.). We excluded vertebrae with fractures or degenerative changes causing BMD more than 1 standard deviation (SD) greater or lower compared with the immediately adjacent vertebrae, in accordance with the International Society for Clinical Densitometry rules for excluding individual vertebrae [24]. Osteopenia was defined as a BMD T-score below −1.0 and osteoporosis as a BMD T-score below −2.5 at any site of the lumbar spine, femur neck and total hip. T-scores were calculated using the reference ranges for Asian populations provided by the manufacturer.

2.3. TBS calculations

Lumbar spine TBS was calculated at the same regions of interest used for BMD measurements using TBS iNsight software (Version 2.1, MedImaps, Bordeaux, France). Lumbar spine TBS was calculated as the mean value of the individual measurements for vertebrae L1–L4. We also performed analyses after excluding the TBS values for the corresponding vertebrae that were excluded in the BMD analyses. TBS values were calibrated to standard values for Hologic densitometers using the TBS phantom. Study subjects were categorized into three groups according to their TBS values: high risk (<1.230), intermediate risk (≥1.230 and ≤1.310), and lowest-risk (>1.310) [25].

2.4. Diagnosis of vertebral fracture

Lateral radiographs of the thoracic and lumbar spine were obtained in the upright position for all subjects. Vertebral fractures were identified on lateral X-ray films of the thoracic and the lumbar spine according to the semiquantitative method of Genant et al. [26] by a trained radiologist blinded to lumbar spine BMD and TBS. Imaging was performed on the same day as DXA. The severity of a fracture is assessed solely by visual determination of the extent of vertebral height reduction and morphological change. Using the Genant et al. semi-quantitative (SQ) method, severity of vertebral fracture were ranked as follows: generally without direct vertebral measurement as normal (grade 0); mildly deformed (grade 1: approximately 20–25% reduction in anterior, middle, and/or posterior height); moderately deformed (grade 2: approximately 25–40% reduction in anterior, middle, and/or posterior height); and severely deformed (grade 3: approximately 40% or greater reduction in anterior, middle, and/or posterior height) [26].

2.5. Statistical analysis

Data are expressed as mean with standard deviation (SD). The study subjects were further categorized according to the WHO classification-normal, osteopenic, and osteoporotic-and all the comparative analyses were performed in osteoporosis or osteopenia/normal BMD groups. Fracture incidence was calculated in each group by dividing the number of subjects with vertebral fractures by the number of subjects in the group. The normality of the distribution was tested using the Shapiro-Wilk normality test. The TBS had a normal distribution, but not LS BMD. Therefore, we applied the Student's *t*-test for comparing TBS, but used the Wilcoxon rank sum test for comparing LS BMD in each group. TBS and BMD were also compared by ANCOVA after adjusting for age and BMI between fracture or non-fracture groups. The relationship between TBS and LS BMD were investigated using the Pearson correlation. Odds ratios for vertebral fracture with confidence intervals (OR [95% CI]) were computed per SD decrease in LS BMD and TBS after adjusting for age and BMI. Prediction models for vertebral fractures incorporating TBS and LS BMD in addition to femur neck BMD and age were developed using the logistic regression model. The Receiver Operating Characteristic Curve (ROC) analysis was studied and difference in are under curve (AUC) between models was tested by the nonparametric method introduced by Delong and colleagues [27]. All statistical analyses were performed using SPSS 20.0 software and STATA 14.0.

3. Results

A total of 929 subjects aged from 50 to 92 years old were included. Their baseline characteristics are shown in Table 1. Their mean age was 67.1 ± 10.1 years, and their mean BMI was 25.1 ± 3.5 kg/m^2. In regard to their bone profiles, the mean LS BMD was 0.868 ± 0.141 g/cm^2, LS T-score was −1.13 ± 1.31 and mean TBS 1.264 ± 0.094. The study subjects included 158 (17.0%), 461 (49.6%), and 310 (33.4%) subjects with normal BMD, osteopenia, and osteoporosis, respectively. The prevalence of radiologically-confirmed vertebral fractures was 9.9% (92/929), and 59 fractures were occurred in osteoporosis, 29 fractures in osteopenia, and only 4 fractures in normal BMD (Table 1). From a total of 92 fractures, 17 were grade 1 severity, 45 (48.9%) were grade 2, and 30 (32.6%) were grade 3. The grade 1 compression fractures account for 15.3% (9/59) of osteoporotic fractures, 20.7% (6/29) of osteopenic fractures, and 50% (2/4) of fractures with normal BMD. Grade 2