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Evaluation of Bone Mineral Density in Proximal Region of Femur by Dual Energy X-ray Absorptiometry

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Abstract

The bone mineral density (BMD) of the proximal region of femur specimens was measured by dual-energy X-ray absorptiometry (DXA). BMD measurement of proximal femur by DXA was influenced according to the depth of water by way of the body thickness. The BMD of the Ward's triangle, and then the trochanteric area was significantly lower detected than the femoral neck through the depth of water. Notable error occured at 28 cm or more depth of water.

The BMD of the femoral neck was not almost affected by the position of the hip from neutral to internal rotation. The position from neutral to external rotation of the hips is desirable as the limb position for DXA. The BMD of femoral neck is thought to be appropriate for the diagnosis of osteoporosis and detection of a risk factor of femoral neck fracture.

Introduction

In recent years, in association with aging of the society, an increase in the population of bedridden aged people has caused a social problem. Among underlying disease of bedridden aged people, the proximal femoral fracture is responsible for the the bedridden state and dementia. Owing to the underlying osteoporosis, even weak external force causes multiple fractures in aged people. Therefore, prevention, diagnosis and treatment of osteoporosis are important for the aged.

Dual energy X-ray absorptiometry (DXA) has been developed as an accurate, highly-reproducible, non-invasive method of bone mineral analysis, and it is recently applicable.[1)]

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However, no agreement has been established with respect to the site of measurement; generally, the front or lateral side of the lumbar spine, the proximal region of the femur, the distal region of the radius or the calcaneus are widely used. The ratio of cortical bone to spongy bone differs on the anatomical region, which is selected according to the purpose of the analysis.[2] In addition, the results of the measurements are affected by the composition in body thickness, respiration, deformity of bone, calcification of surrounding tissues, or the limb position; these problems are unsolved yet.[3] Because the proximal region of the femur generally suffers little deformation and the body thickness of this region is not affected by respiration, this region is thought to be suitable site for bone mineral analysis. While the accuracy of analyses is markedly advanced, this study was carried in order to investigate the influence of the body thickness at the level of the proximal region of the femur and the limb position on the measurement of DXA. In relation to the clinical significance of bone mineral analysis of the proximal region of the femur, its thereshold value for the fracture and the prospect of the fracture on the bone mineral density was a matter of great importance in aged patients with severe osteoporosis.

Material and Methods

The main analytical equipment was a DXA system (Hologic Co.;QDR-1000/W). The samples were specimens of the proximal region of the femurs isolated from the hips of aged cadavers which had been subjected to systematic anatomy. The soft tissues of specimens had been removed. A total of such 19 specimens were used for the study. The measurement of the bone mineral content (BMC) and bone mineral density (BMD) of the femoral region was studied as follows using an experimental model. The proximal femoral specimen was fixed at the neutral position in a container made of acrylic resin, and water was filled up to a level of 10 cm. BMD of the neck, trochanter and Ward's triangle of the femur was measured by manually setting each measuring site of DXA. The water level was increased at 2cm intervals, and the same measurements were performed at each water level. In order to study the error of measurement according to the limb position, each of the 19 femur specimens was placed at 30° internal rotation, 30° external rotation, 30° adduction, 30° abduction, 30° flexion, and 45° flexion. The neck, trochanter and Ward's triangle of the femur were measured for BMD, and the results were compared with those obtained at the neutral position.

Results

When the water thickness was increased from 10 cm up to 26 cm at 2 cm intervals, BMC decreased as the thickness increased There is no change of the area in all femoral regions. As a result, BMD also decreased (r (coefficient of correlation) >-0.9; Fig.1). When the water thickness was 28 cm or more, BMC of the trochanter markedly increased, which caused a marked error in BMD of the trochanter (Fig. 1).

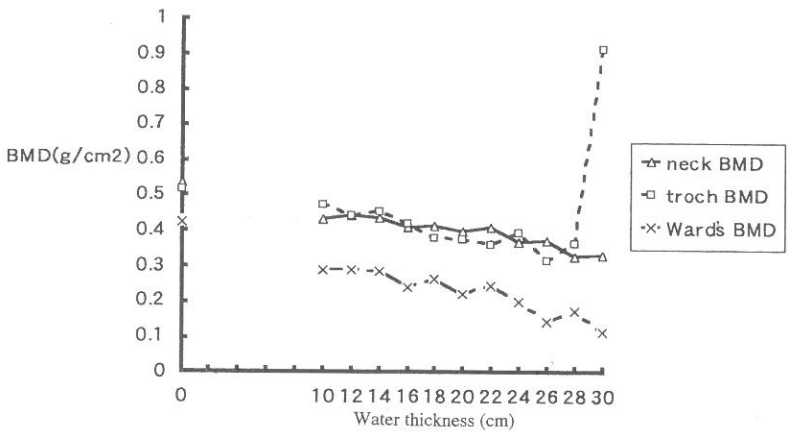

Figure 1. Effet of the depth of water on BMD measurement of proximal femur from aged cadavers with DXA.

However, in the case of the neck, which is rich in cortical bone, the error of measurements of BMC and BMD was smaller than in that of the trochanter. The coefficient of correlation was almost the same as those recorded at a water thickness of 26 cm less.

In the measurements of BMD at various limb positions, both adduction and abduction ($\leqq$ 30°) did not result in any significant changes in the BMC or BMD for any femur regions. On the other hand, at angles exceeding 30°, the measurement of DXA was impossible because the area of measurement could not be detected (Fig. 2). The effects of 30° internal rotation caused an increase of 9.7% in the area of the neck region relative to the values obtained at the neutral position, while decreases of 4.0~9.2% were noted in the area of the other bone region, and BMD decreases in the trochanter, while it increased in the neck and Ward's triangle. Due to the differences in the rate of change, BMD decreased in the trochanter but increased in the other bone region. In comparison with the neutral position, external

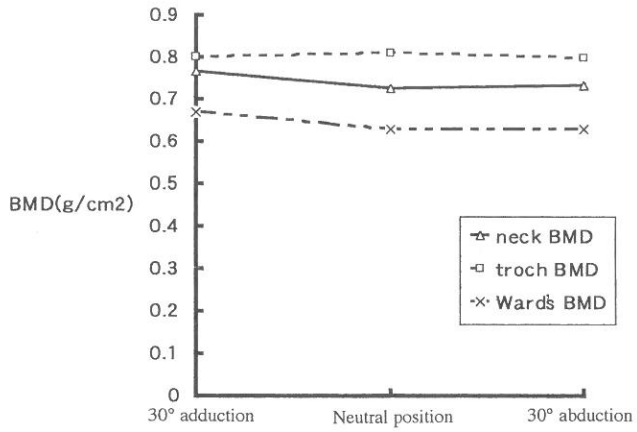

Figure 2. Effect of adduction/abduction of proximal femur from aged cadavers on BMD measurement with DXA.

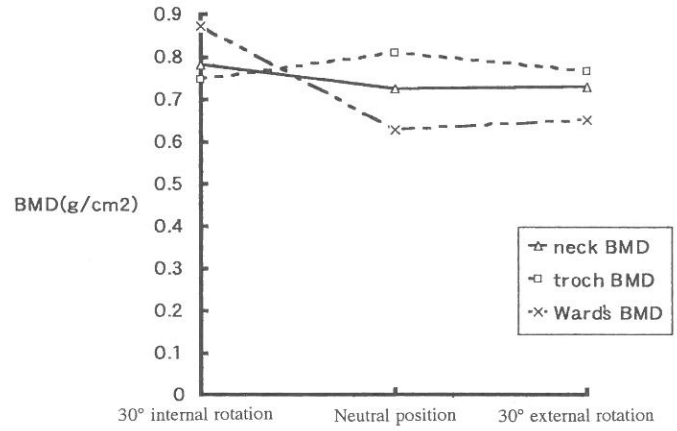

Figure 3. Effect of rotation of proximal femur from aged cadavers on BMD measurement with DXA.

rotation did not cause significant changes of BMD in any femoral regions (Fig. 3). In the case of flexion, the area of each femoral region decresed. In flexion of 30° or less, no significant changes were noted in BMD (Fig. 4). Regardless of limb position, the area of Ward's triangle showed a constant value.

Discussion

In another study of the accuracy of measurement by DXA, a K_2HPO_4 solution is used as a water phantom, and BMD is measured while changing the water depth. In such system, BMD has

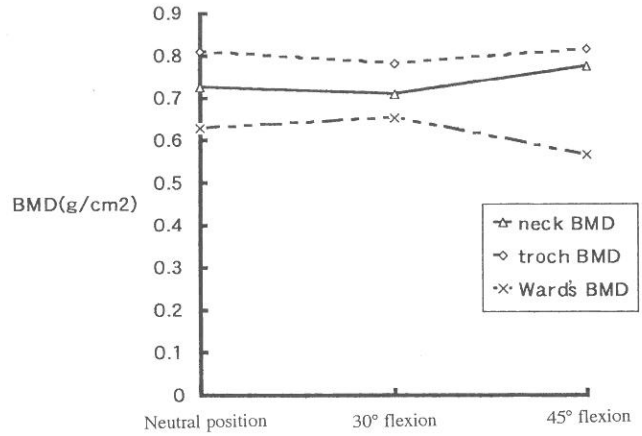

Figure 4. Effect of flexion of proximal femur from aged cadavers on BMD measurement with DXA.

been reported to show no significant changes within a water depth range from 10 cm to 30 cm. In the present study, we measured BMD using proximal femur specimens, which were obtained from cadavers subjected to systematic anatomy, by changing the depth of water from 10 cm to 30 cm at 2cm intervals. As a result, as the depth was increased, BMD decreased because of a reduction of intensity of X-ray through the water; at a depth lager than 28 cm, BMD was over-estimated. Thus, BMD measurement was surmised to be affected by the constitution of the water. The density of the K_2HPO_4 solution is 1.12g／cm^3, which is larger than the actual bone density, and thus its density measurement is not affected by the water thickness within a range from 10 cm to 30 cm.

On the other hand, in the case of measurement of BMD, since BMD from cadaver is lower than that of the K_2HPO_4, different errors are produced in each femoral region[3]. The femoral neck region which is rich in cortical bone was found to be a bone region that is less likely to be affected by the water thickness. Because measurement of BMD in another femoral region is markedly affected by the constitution of the water, the BMD of the femoral neck region should be employed as the standard in quantitative evaluation of osteoporosis [4-5].

In bone mineral analysis, compared with internally rotated hip positions, the apparent size of the femoral neck region apparently becomes shorter in the neutral position, and the intertrochanteric crest overlaps the neck region, resulting in an overestimation of BMC of the neck with about 12%. The range of motion of the hip joint is restricted in most of aged people. Therefore, if they are forced to take an internally rotated hip position, the pelvis slopes, and it

is thus difficult for femurs to be internally rotated with strictly 30°.

In regard to the reproducibility of BMD measurement of hip in our study using proximal femoral specimens, there were no significant differences between the neutral position and externally rotated hip positions. Thus, the improvement of reproducibility of measurement at the neutral position or an externally rotated hip position, rathar than an internally rotated position, made femur to be more appropriate site for BMD.

Osteoporosis has been identified as a risk factor of fracture on the basis of retrospective studies [6-7]. Clinical significance of bone mineral analysis provides the information for diagnosis of osteoporosis and evaluation of therapeutic efficiency on osteoporosis. There has been also reports of studies on threshold of fracture [8-9]. Because many aged patients suffer degeneration of bone or arterial calcification and there is no changes of body thickness due to respiration, BMD of the neck region of the femur is thought to be appropriate site for diagnosis of osteoporosis and detection of a risk factor of the femoral neck fracture. There have been few reports of studies for the results of corrective fixation of the proximal femur, the result of replacement of artificial prosthesis and the effects of complication of dementia on BMD.

In order to prevent femoral neck fracture, which is likely to occur in bedridden aged people, and evaluate the prognosis of the fracture, clinical significance of bone mineral analysis is predicted to be recognized moreover in the future. BMD measurement of the femoral neck by DXA is achieved with a good precision[10]. And the femoral neck is a sensitive region to evaluate the early cortical bone loss of premenopausal or postmenopausal women by way of the follow up as to the decrease of BMD with aging.

Summary

1. In measurements of the bone mineral density (BMD) of the proximal region of femoral specimens, water thickness, which was used as the substitute of body constitution, affected the measurements of DXA. At water thickness of 28 cm or larger, the reliability of the data was poor.
2. The neutral to external rotation of the hip position is desirable for the measurement of BMD.
3. The BMD of the proximal femur is thought to be appropriate for diagnosis of osteoporosis and detection of a risk factor of femoral neck fracture.

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