Evaluation of Bone Mineral Density of the Necrotic Area in Osteonecrosis of the Femoral Head Using Quantitative Computed Tomography

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Introduction: The collapse in osteonecrosis (ON) of the femoral head causes hip pain and possibly induces secondary osteoarthritis changes. It is speculated that collapse may be induced with the advance of bone structure weakness, which may relate with bone mineral density (BMD) loss. In previous study, we confirmed that the change of bone mineral density of the lateral sides of the femoral head in ON using dual energy x-ray absorptiometry (DEXA) was significantly higher in stage 3 or 4 on the classification of Ficat1. Although, the bone structure including BMD may closely relate with collapse of the femoral head, the measurement of the femoral head by DEXA included bone sclerosis, it was not possible to measure BMD in the necrotic area independently. In this regard, there is a crucial limitation of the measurement of BMD using DEXA. We aimed to measure the BMD of the necrotic area independently using quantitative computed tomography (qCT). The aim of this study was to investigate BMD of the necrotic area in ON of the femoral head comparing with the normal area using qCT.

Methods: A total of 46 hips of 31 patients (male, 15; female, 16) diagnosed with ON by magnetic resonance image (MRI) findings were enrolled in this study. The average patient age was 42.8 years (range, 22-75). The cause of ON was idiopathic in 6 hips, related to steroid use in 32 hips, related to alcohol abuse in 7 hips, and traumatic in 1 hip. There were 11 hips with stage 1, 9 hips with stage 2, 22 hips with stage 3, and 4 hips with stage 4 according to the classification of Ficat. Among them, 46 hips were classified into two categories: collapse group (26 hips) whose stage was 3 or 4 at the time of qCT, and non-collapse group (20 hips) whose stage was 1 or 2. qCT and radiographic evaluation were performed at almost the same period (before or after three months) in all cases. Region of interest (ROI) of the femoral head was defined separately for the necrotic area and normal area, then BMD in each of ROIs were evaluated to compare between collapse group and non-collapse group.

Next, among the 46 hips, 10 hips of 10 patients (male, 4; female, 6) with a mean age of 52.3 years (range, 30-75 years) who were diagnosed as unilateral ON were selected. There were 1 hip with stage 2, 5 hips with stage 3, and 4 hips with stage 4. The symmetrical region of affected side was defined as contralateral region, and BMD in the contralateral area was evaluated as a reference BMD including the stage of all (Figure 1).

Figure 1. Definition of ROI of the femoral head
P values of less than 0.05 were considered statistically significant.

Radiographic evaluations were performed on the classification of Ficat, and measured the amount (mm) of collapse of the femoral head.

We measured the BMD values in the necrotic area, normal area, and contralateral area as ROIs of the femoral head using qCT. CT number of cancellous bone in each areas was measured, and the BMD values were estimated from CT number using a bone mineral reference phantom (B-MAS 200; Kyoto-Kagaku, Kyoto, Japan). This phantom contained five chambers filled with different concentrations of hydroxyapatite (0, 50, 100, 150, and 200 mg/cm3), and CT number was measured by each hydroxyapatite concentration.

ROI of the necrotic area was identified in each axial image of the femoral head which is compared with same slice by MRI, and we measured CT number of each region.

**Results:** The average BMD was 312.6±53.1 mg/cm3 in the necrotic area of collapse group, 324.1±80.7 mg/cm3 in the necrotic area of non-collapse group. The average BMD was 225.7±56.7 mg/cm3 in the normal area of collapse group, 231.4±53.5 mg/cm3 in the normal area of non-collapse group. BMDs in the necrotic area of both collapse group and non-collapse group were significantly higher than the normal area of both collapse group and non-collapse group (P<0.01) (Figure 2).

Figure 2. Evaluation of BMDs for collapse
In unilateral affected group (N=10), the average of BMD was 309.3±46.9 mg/cm³ in the necrotic area among the 10 hips, 216.3±57.0 mg/cm³ in the normal area, and 205.6±49.1 in the contralateral area. BMD was significantly higher in the necrotic area among 10 hips (P<0.01) (Figure 3).

Figure 3. Evaluation of BMDs in each of ROIs
Discussion: In this present study, we investigated BMD of the necrotic area in ON of the femoral head using qCT. BMD in the necrotic area was significantly higher than normal area of the femoral head. The strength of our investigation was that we evaluated BMD in the necrotic area of the femoral head in ON independently, which was impossible by DEXA measurement. In order to implement this object, ROI of the necrotic area was identified in each axial image of the femoral head compared with same slice by MRI, and identified the accurate necrotic and normal area in same slice. Then, we measured CT number of each region compared with reference phantom.

Although the mechanism of BMDs change in the necrotic area should include several factors. For instance, several studies2, 3, 4 have shown that the status of bone metabolism in the necrotic area was accelerated comparing with the normal area of the femoral head in ON by the immunohistochemical analysis using the human specimens. Thus, the status of the bone metabolism is possibly accelerated in the necrotic area. Although the balance of bone metabolism, i.e., bone formation or resorption, is still unclear, the increase of BMD in the necrotic area that was confirmed by the current study may be related with these bone metabolism changes.

One of the limitations of this study is some other factor such as body weight, BMI, patient activity or use of bisphosphonates may possibly influence the collapse and BMD of the femoral head.

In conclusion, we demonstrated that BMD in the necrotic area was significantly higher than the normal area of the femoral head by independent measurement using qCT. Further, investigations are needed to reveal the pathophysiology of this BMD increase in ON of the femoral head.

Significance: BMD in the necrotic area of the femoral head in ON using qCT was significantly higher than the normal area of the femoral head.

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