Association between uptake in 18F-fluoride PET and mechanical load stress in the hip joint

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Background
18F-fluoride Positron Emission Tomography (fluoride-PET) is a functional imaging technique that mainly detects the acceleration of bone metabolism. We previously demonstrated the usefulness of fluoride-PET in various stages of hip osteoarthritis. Interestingly, the uptake was recognized even in the case without marked radiographical findings. The significant uptake in fluoride-PET in the hip joint, which is caused by the acceleration of bone metabolism in the subchondral bone, may be related with the mechanical load stress concentration due to some morphologic factor. However, there have been no previous studies that examined the relation between uptake in fluoride-PET and mechanical stress.

The purpose of this study was to calculate stress distribution from computed tomography (CT) data of hips with coxalgia or dysplastic change by using the finite element analysis (FEA) method, and to examine its association with the uptake in fluoride-PET.

Method
A total of 30 hips (15 cases) with radiographic dysplastic change or osteoarthritis or no abnormality were enrolled in this study. Each case was investigated by fluoride-PET and CT. The stress distribution in each hip joint was calculated by FEA, and the maximum standardized uptake value (SUVmax) in fluoride-PET was measured as an index of accumulation. The existence of hip pain was reviewed for each joint. We also investigated the influence of hip pain in results of fluoride PET and FEA.

FEA Three-dimensional models of the hip were made from the CT data. After adding the information about loading conditions, finite element analysis was performed using Mechanical Finder V6.0 (Research Center of Computational Mechanics, Inc.).

Results
A significant correlation was confirmed between SUVmax and stress in all 30 hip joints, including both the affected and normal sides. (r=0.69 p=0.0074)

Discussion
This is the first study to investigated the association between the acceleration of bone metabolism and mechanical stress concentration in the hip joint. In twenty hips, the high-uptake regions in fluoride-PET and the regions of stress concentration in FEA were the same. These results suggest that the acceleration of bone metabolism detected by fluoride-PET was caused by the mechanical stress concentration. Previously, Kuriwaka et al reported that the mechanical stress accelerates the bone metabolism in animal model.

We confirmed high mechanical stress and high SUVmax in 8 hips without any dysplastic change or osteoarthritic change. In these cases, mechanical load stress were increased by some factors, and that may contribute the acceleration of bone metabolism in subchondral bone. These results also suggest that bone metabolism increased before radiographical change in plain X-rays occurred. On the other hand, we also recognized two cases who had a low SUVmax but high von Mises stress in the hip joint. The mechanical stress concentration in the hip thus possibly occurred before the increase in bone metabolism.

In conclusion, high-uptake regions in fluoride-PET and regions of stress concentration were associated in hip joints with dysplasia or osteoarthritis, and a significant correlation was confirmed by quantitative evaluation. Further studies are needed with more cases and with multifactorial evaluations.