Evaluation of Local Bone Remodeling by 18F-fluoride Positron Emission Tomography in Stress Shielding Region after Total Hip Arthroplasty

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Introduction: Total hip arthroplasty (THA) has been recognized as a useful operation and undergone in all over the world, but stress shielding is still an issue that occurs with the advance of the bone mineral density (BMD) loss around femoral implant. This phenomenon possibly complicates the revision surgery due to difficulty of implant fixation and may increase the risk of fracture around the implant. The mechanism of stress shielding probably relates with local changes of mechanical stress property, which may possibly affect the bone remodeling status, i.e. osteoblast/osteoclast activity. However, the actual bone remodeling status in stress shielding region is unclear. 18F-fluoride PET, which we utilized in this study, is capable of evaluate bone remodeling status reflecting the osteoblasts activity. We previously reported its utility for evaluating septic and aseptic loosening of implant1. We hypothesized that 18F-fluoride PET may show some specific property in stress shielding region. The purpose of this study was therefore to evaluate the local bone remodeling activity in THA cases with stress shielding using 18F-fluoride PET, and to reveal relationship between bone turnover and stress shielding.

Methods: We enrolled total of 88 hip joints from 70 cases (female, 53; male, 17) of THA (primary; 77, revision; 11). The exclusion criteria were infection, hip resurfacing arthroplasty, and cases with massive osteolysis. The average age was 69(30-87) years and the average duration after THA was 11.2(1-35) years. 18F-fluoride PET was performed for each case at least one year after THA, and then radiographic evaluation and clinical evaluation was performed at the same period (3 month before or after PET scanning). Gruen classification was applied both for X-ray and 18F-fluoride PET images.

(PET) SET-2400W (Shimadzu Corporation, Kyoto, Japan) was used for PET scanning. A whole-body image was obtained 40 minutes after the injection of 185MBq of 18F-fluoride. The average standardized uptake value (SUVaverage) and the maximum (SUVmax) was measured by a coronal image for each joint. All SUV obtained from each zone on the prosthetic side were divided by the SUV from the metaphysis on the same side to compensate the differences individual bone turnover.

(Radiographic evaluation) In the plain X-ray of bilateral hip joints with standing position, the existence of stress shielding was evaluated by two individuals. When agreement was obtained between observers, we identified the existence of stress shielding.

Results: The mean SUVaverage ratios in each zone were 2.0 in zone1, 2.0 in zone2, 1.9 in zone3, 1.4 in zone4, 2.0 in zone5, 2.2 in zone6, 2.5 in Zone7 in stress shielding group, while they were 2.3, 2.0, 1.9, 1.4, 2.0, 2.2, and 2.6 respectively in non-Stress shielding group. There is no significant difference between two groups in all zones (Figure2). The difference in the SUVmax is similar with that of SUVaverage. The femur was divided into three groups: proximal (Zone1, 7), middle (Zone2, 6), distal (Zone3, 4, 5). The SUVaverage ratios in each part are 2.3, 2.1, 1.8, and SUVmax ratios are 2.7, 2.5, 2.2, respectively (Figure3). Both The SUVaverage and max in the proximal are significantly higher than in the distal. (p<0.01).

Figure 2 SUVaverage ratio of stress shielding and non-stress shielding groups.
Discussion: In this study, we found that the activity of bone remodeling does not decrease even in the area where stress shielding was observed. This is the first observation to reveal local bone remodeling status in stress shielding region after THA. Our result indicates that osteoblasts are not inactivated after THA especially in proximal side, where stress shielding is usually observed rather than distal side.

In recent similar studies utilizing SPECT for evaluating changes in bone turnover around implant, Venesmaa et al have described that the uptake did not correlate with changes in periprosthetic BMD. Also, Heikki et al. have shown that increased periprosthetic SPECT uptake is associated with increased bone loss. These observations are basically compatible with our current results. The strength of our study compared to those previous studies are that our study has more cases with longer-term observation periods at least one year after THA, and that PET imaging has the advantages over SPECT in terms of the sensitivity and accuracy evaluating a condition of metabolic turnover in vivo.

The implication of present study is that osteoblast activity is maintained even in stress shielding region, which suggests osteoclast activity may relatively contribute to BMD loss around implant. On the other hand, the effect of bisphosphonates (BPs) for preventing pelvic and femoral periprosthetic bone loss after THA has been reported. The relationship between bone turnover and stress shielding shown in this study is supportive for use of BPs after THA. Further investigations are needed to confirm the differences between implant type or influence of loosening.

Significance: This study found that the activity of bone remodeling does not decrease even in the area where stress shielding was observed. This is the first observation to reveal local bone remodeling status in stress shielding region after THA.

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References:
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