MRI T1 map value can be a prediction of bone strength of cancellous bone.

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Introduction: Bone fragility is associated with bone quality as well as bone volume. Patients with poor bone quality tend to have more chance to experience fractures compared to patients with normal bone quality. Despite strong correlation between bone mineral density (BMD) and biomechanics, BMD fails to capture changes in bone quality and remains arguably an imperfect predictor of fracture risk in patients with poor bone quality. Magnetic resonance imaging (MRI) has the potential to illuminate changes in bone and bone marrow, and therefore has potential to be as a noninvasive diagnostic tool for the bone quality. Although MRI cannot directly acquire the information regarding the trabecular bone quality, recent studies suggest that the water content and bone marrow adipose tissue (BMAT), which can be evaluated by MRI T1 mapping, are associated with pathogenesis of osteoporosis1. However, before applying MRI T1 mapping to clinical trials, they must be validated in exposed bone. In this study, we aimed to examine whether MRI T1 map values correlate with biomechanical properties of cancellous bone using harvested bone specimens of femoral head.

Methods: The local ethics committee in Hokkaido University has approved this study. Five osteoarthritis patients ready to operate total hip arthroplasty underwent 3T MRI (Achiva, Philips Netherlands) examination to acquire T1 and T2 map value. Total of 50 cubic cancellous bone specimens with 5x5x5mm in size were obtained from five femoral heads using a diamond wheel saw. The specimens were scanned by micro-computed tomography (micro-CT; InspeXio SMX-90CT, Shimadzu, Japan) and structural indices and volume BMD (vBMD) were calculated using the Boneel software (Copyright Michael Doube). The specimens were then subjected to mechanical testing. The samples were continuously compressed in gravity direction up to 0.36 strain with 0.05 mm/min. This condition is used to acquire post-yield minimum stress as well as yield stress, elastic modulus of cancellous bone (Fig. 1).2 Post-yield minimum stress represents the risk for collapse or re-fracture of cancellous bone after initial fracture. Pearson’s correlation coefficient (r) was calculated and considered to be significant at p < 0.01 (JMP Pro software Version 12.0.0 SAS Institute Inc., Cary, NC, USA).

Results: T1 map value correlated with yield stress (r = 0.50) and elastic modulus (r = 0.42). Radiographic analysis demonstrated a positive correlation with T1 map value and microstructure of cancellous bone such as bone volume fraction (BV/TV, r = 0.49) and trabecular thickness (Tb.Th., r = 0.40). Minimum stress, which represents stress causing re-fracture or collapse of cancellous bone after initial fracture, had high correlation coefficient with T1 map (r = 0.66) and T2 map (r = 0.44) as well as BV/TV (r = 0.68), vBMD (r = 0.67), Tb.Th. (r = 0.60), and Tb.Sp. (r = -0.37), suggesting that collapse risk of cancellous bone after initial fracture can be predicted by MRI T1 and T2 mapping. There is one problem in MRI based prediction, however, that T1 map value did not correlate well with minimum stress of cancellous bone in specimens with low vBMD.

Discussion: The results of this study demonstrated that MRI T1 map value has positive correlation with yield stress and elastic modulus of cancellous bone. Although structural parameters of cancellous bone correlate well with biomechanical properties of cancellous bone, these information can be obtained by high resolution computed tomography scanning, by which patients expose to high-dose radiation. Therefore, MRI T1 mapping can be an alternative diagnostic tool for the prediction of fracture risk. Prediction of collapse/re-fracture risk after initial fracture is also of importance in clinical practice because progressive collapse of cancellous bone following fragility fracture such as insufficiency fractures of vertebral body and femoral head leads to a variety of comorbidities: chronic pain, malalignment, and impaired musculoskeletal functions. Therefore, MRI based prediction of minimum stress might be useful in determining the need for brace treatment and bed rest. One of the problems in MRI based prediction of bone strength found in this study is that MRI T1 and T2 map values do not correlate well with minimum stress of cancellous bone in specimens with low vBMD.

Significance: MRI T1 mapping can be a surrogate to bone strength of cancellous bone but we have to be careful when applying it to the patients with low BMD.

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References

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