Three-dimensional distribution of T2 mapping in healthy knee cartilage in vivo

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Introduction
Quantitative knee MR imaging, such as delayed gadolinium enhanced MRI of cartilage (dGEMRIC) and T2 mapping, provides reliable, non-invasive assessment of microstructure compositions of the articular cartilage. T2 mapping of the articular cartilage is one of the recent noteworthy techniques in joint MR imaging, to elucidate early degenerative change associated with change of water contents and damage to collagen network. [1] Although some studies demonstrated potential of 2D T2 mapping for assessing cartilage degeneration, they were restricted to evaluation of limited area in the whole anatomical configuration, due to availability of few imaging planes at the femorotibial joints. Hence, there may be undetected, abnormal cartilage lesions which were located out of the imaging section in those imaging techniques. Three-dimensional (3D) distribution of the articular cartilage thickness in the knee joint has been studied quantitatively using MR imaging in conjunction with computational processing techniques [2], however few studies assessed T2 mapping of articular cartilage in three dimensionally. The purpose of this study is to assess 3D-T2 mapping of femoral cartilage of healthy knee joints in vivo, and investigate the correlation with 3D distribution of healthy cartilage thickness.

Material and Methods
All participants provided informed consent to participate in the study, which was approved by the Institutional Review Board. 14 healthy subjects (24-38 years old, 7 male and 7 female, 7 left and 7 right) with no knee pain and no previous history of knee injury participated in this study. Each subjects’ knee was imaged using a 3D fast image employing steady-state acquisition cycled phases (Fiesta-C) sequence and T2 maps at 3.0T MR imaging system in the sagittal direction with the subject lying supine. Fiesta-C images were acquired (TR, 12.7 ms; TE 6.3 ms; field of view, 12 cm; matrix, 512 x 256; slice thickness, 1.5 mm; signal averaging, 1; acquiring time, 10 min and 27 s). T2 maps were generated using a monoexponential fit from 2D multi-scan echo sequences (TR, 1500 ms; 6 echoes between 10-80 ms; field of view, 12 cm; matrix, 320 x 256; slice thickness, 3 mm; signal averaging, 1; acquiring time, 12 min and 54 s), in which consecutive imaging sections without interposition spaces were obtained by interleave acquisition techniques. In both sequences, the same sagittal imaging planes were obtained in each subject using identical axial localizing images. Cartilage region were manually traced in each Fiesta-C image in custom-made software, and used to construct 3D anatomic models of the femoral cartilage. 3D T2 mapping of femoral cartilage was constructed by onlaying T2 value at corresponding spatial zones of the 3D-anatomical models. (Fig 1) We assessed regional T2 mapping of femoral cartilage by dividing into three regions of interest (ROIs), trochlea of the femur (TrF), medial femur (MF), and lateral femur (LF). TrF was used for aspects of the femoral cartilage located anterior to the intercondylar notch, and MF and LF for the medial and lateral aspects of femoral cartilage posterior to it. The ROIs of the femoral cartilage of MF and LF were designated to be divided into an external and an internal subregion (eMF, iMF and eLF, iLF). (Fig 2)

Results
By the overall inspection of 3D-T2 and 3D-thickness mappings, anterior and posterior portions on the medial and lateral femoral cartilages tended to show higher T2 values and lower thickness, as compared to the intermediate portions (Fig 1). The average T2 values of femoral cartilage were 39.6±3.5ms/38.3±2.9ms in the medial/lateral condyle, and the average thickness were 1.7±0.3mm/1.7±0.3mm in the medially/lateral condylar respectively. Cartilage T2 values at eMF/iMF/eLF/iLF were 38.5±3.7ms/40.6±3.5ms/37.1±2.8 /39.6±2.6ms/37.2±2.3ms,respectively. (Fig 3a) There were no significant differences among ROIs. Cartilage thickness at eMF/iMF/eLF/iLF were 1.6±0.2mm/1.7±0.3mm/1.6±0.3mm /1.7±0.2mm/2.1±0.4mm, respectively. Cartilage thickness in TrF had significantly higher values, compared to other ROIs (p < 0.05).

Discussion
The present study is the first to reveal characteristic patterns of cartilage 3D-T2 mapping in normal knees in vivo. In this study, T2 value and the thickness of femoral cartilage had site-dependent variation. So, care should be taken when assessing the change of cartilage condition which is related with osteoarthritic involvement or intrinsic cartilage structure in the local area. The present finding that enabled to assess quantitatively whole femoral cartilage of knee joint may aid in understanding the normal morphology and condition of the femoral cartilage. 3D-T2 mapping may make it easy to detect cartilage degeneration which is difficult to detect by 2D-T2 mapping.

References