Topographic variation of T2 value in hip articular cartilage at 3T

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Introduction

T2 mapping is an MR imaging technique that can evaluate the hydration and collagen fiber integrity in articular cartilage[1]. It has been known that the water concentration and arrangement of the collagen network structure in the cartilage, which may be reflected in T2, may change according to location in the joint[2]. In addition to the variation of cartilage matrix composition in the joint, T2 of cartilage has been known to be sensitive to the relationship between the collagen network and orientation of the static magnetic field (B0) due to the orientation dependent dipolar interaction[3]. To inspect the cartilage degeneration, it is important to understand the regional differences of T2 in a specific joint. The aim of this study was to obtained baseline T2 for normal cartilage in healthy volunteers, especially focusing on topographic variation.

Methods and Materials

Twenty four healthy hip joints from 12 volunteers were studied (6 men, 6 women). Mean age at the time of MR imaging was 29.5 ± 4.9 [24-36] years (mean ± SD, [range]). Exclusion criteria were history of hip pain, or abnormality or trauma of lower extremity requiring medical treatment. MR imaging was performed with a 3.0-Tesla system (Trio; Siemens, Erlangen, Germany) with a multi-array abdomen coil. A multi-spin-echo (MSE) sequence was used for T2 measurement. An oblique coronal plane, which was parallel to the femoral neck and passed through the center of the femoral head, was acquired The MSE scanning parameters were 1500 msec repetition time, ten echo times of 10.3-103 msec, 150×150 mm field of view, 4.0 mm slice thickness, 512×512 matrix, and 1 excitation. Total scan time for this sequence was 17 minutes 41 seconds per hip joint. T2-calculated maps were generated using MATLAB software (Mathworks, Natick, MA) with mono-exponential curve fit. To evaluate topographic variation of T2 in hip cartilage, the femoral cartilage was divided into 12 radial sections (Figure 1). Furthermore, each section was divided into 2 layers (superficial and deep), which represented the superficial and deep halves of the cartilage from the articular surface, respectively. For T2 measurements, the region of interest (ROI) was drawn over the whole area of each section and layer.

Results

Cartilage T2 values measured by our MSE sequence in this study were in good agreement with those of previous studies[5]. T2-calculated maps of articular cartilage overlaid on morphological images for a representative subject are shown in Figure 2. Femoral cartilage T2 in the superficial and deep layers were shortest at an angle of -20° to 20° and -10° to 10°, respectively (Figure 3). T2 increased as the angle neared -40° to -50° and 40° to 50°. The greater increase in femoral T2 was observed in the deep layer. Femoral T2 oriented at the angle of -50° to -60° and 50° to 60° appeared to be shorter than those oriented at the angle of -40° to -50° and 40° to 50° in both superficial and deep layer.

Discussion

T2 in both superficial and deep layers of femoral cartilage were longest in the section of -40° to -50° and 40° to 50°, which were located symmetrically with respect to the central line. On the other hand, it is also known that regional T2 will be the longest when collagen fibers are oriented 54.7° relative to B0, which is termed the magic angle[6]. Taking these findings into consideration, one of the main causes of the maximal T2 observed at these sections might be the orientation dependent dipolar interaction. Magic angle effect is supposed to be observed when the collagen network structure is oriented 54.7° relative to B0; however, the angle of the section with the longest T2 measurement was lower in absolute value than expected. One possible explanation for these findings might be that the collagen network structure is not oriented perpendicular to subchondral bone. It has been reported that the orientation of the collagen network structure is not perpendicular to subchondral bone at the periphery[7]. If collagen fibers lean caudally toward the surface of the cartilage at the periphery of the femoral head, it is possible to have a magic angle effect at an angle smaller than expected. In this study, femoral cartilage T2 in the superficial and deep layers were the shortest at an angle of -20° to 20° and -10° to 10°, respectively. One of the causes of the minimal T2 observed at the cranial portion of the cartilage might be the decreased water content of cartilage due to higher pressures on weight-bearing cartilage, as well as the orientation dependent dipolar interaction[8]. In conclusion, our results demonstrate the existence of topographic variation of hip cartilage T2 in young healthy volunteers. These findings can be a comparative standard to evaluate degeneration of hip cartilage in patients.

Figure 1

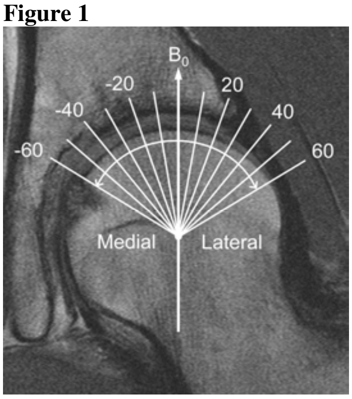

Figure 2

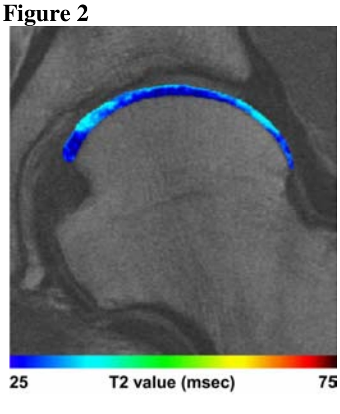

Figure 3

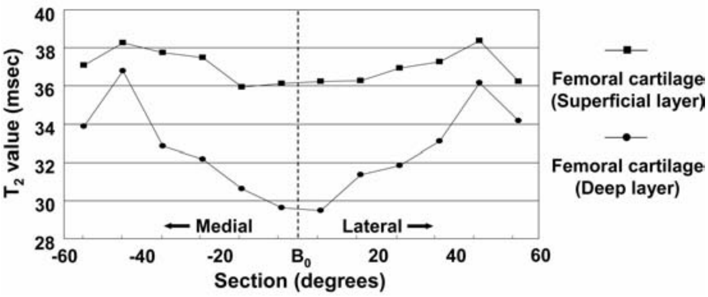

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Figure 1
Division of femoral cartilage. The center of the femoral head was found using a concentric circle and a center line parallel to B0 that ran through the center of the femoral head.

Figure 2
T2 calculated maps of femoral articular cartilage overlaid on morphological images for a representative subject. In the color scale, blue represented areas of short T2 value, and red represented areas of long T2 value.

Figure 3
Average T2 of sections and layers in femoral cartilage for both hips in all patients.