

MR Imaging and Early Cartilage Degeneration Detection

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INTRODUCTION: Interactions between all the major joint tissues, including the articular cartilage, synovium, bone marrow, subchondral bone, trabecular bone and muscle, have been implicated in osteoarthritis (OA) (1). Magnetic resonance (MR) images have been used to quantify the cartilage morphology, volume and thickness (2) and focal defects (3), and may reflect changes in biochemical composition of articular cartilage (4-6). Cartilage loss in OA is preceded by damage to the collagen-proteoglycan matrix and elevation of cartilage water content. These changes are associated with changes in cartilage relaxation times T_2 and $T_{1\rho}$ (7), as well as in the uptake of contrast agents such as Gd-DTPA in the cartilage matrix (dGEMRIC) (4). Furthermore, injury and OA-related changes in bone marrow manifested by an increase in the signal intensity in bone marrow on fat-saturated T_2 -weighted images (bone marrow edema, BME) have been associated with severity and progression of OA (8). Such marrow changes are also associated with acute injuries such as anterior cruciate ligament injuries (9), that sometimes progress to OA and joint degeneration. The purpose of this paper is to review the interrelationships of T_2 , $T_{1\rho}$, cartilage volume and BME in patients with OA versus those with acute knee injury, and markers of early cartilage degeneration.

METHODS: In controls and subjects with OA and ACL injury studies relating cartilage volume, thickness or degeneration to relaxation time T_2 , $T_{1\rho}$ and bone marrow edema changes were conducted. High-resolution, fat-suppressed, sagittal images were acquired for assessing cartilage structure, using a 3-D spoiled gradient echo (SPGR) sequence. The cartilage was segmented using a spline-based, semi-automatic technique and was defined in four distinct regions: medial and lateral tibia, and medial and lateral femur. Total cartilage volume and average thickness were calculated for each region. Sagittal images were acquired for measuring T_2 relaxation time, using a dual echo spin echo sequence. A map of T_2 values was calculated. Using a $T_{1\rho}$ relaxation time mapping technique $T_{1\rho}$ maps were reconstructed. In patients with OA and with ACL (anterior cruciate ligament) tears, who showed BME $T_{1\rho}$ -weighted and fat-saturated T_2 -weighted fast spin-echo images were acquired. Point RESolved Spectroscopy (PRESS) volume selection was used to acquire spectroscopic fat/water quantitative data in the edema. BME was semi-automatically segmented using a threshold method based on T_2 -weighted images and volume of BME was calculated.

RESULTS: The studies revealed that higher medial T_2 results in greater loss of medial cartilage volume

at twelve months. Specifically, the correlation between baseline medial femoral T_2 and change in medial femoral cartilage volume was $r = -0.38$ ($p < 0.05$). A significant correlation was found between average $T_{1\rho}$ and T_2 values within the cartilage, with a correlation coefficient $R^2=0.69$ and $p=0.017$. The increase of average $T_{1\rho}$ in cartilage from the controls to patients was 19.1% (43.90 ms for controls and 52.28 ms for patients), while the increase was 9.6% for the average T_2 (34.94 ms for controls and 38.31 ms for patients). The difference in average $T_{1\rho}$ in cartilage between controls and patients was significant ($p = 0.003$) while it was not significant for average T_2 ($p = 0.202$). Patients with similar average T_2 may have different $T_{1\rho}$, or vice versa. The average $T_{1\rho}$ values in BME-overlying cartilage were significantly higher than that in surrounding cartilage (51.8 ± 10.8 ms vs. 43.0 ± 8.3 ms, $p=0.032$). Volume of BME correlated significantly with volume of elevated water ($R=84.4\%$, $p=0.004$) but not with volume of elevated unsaturated lipids.

DISCUSSION & CONCLUSIONS: Quantitative imaging appears promising and may potentially provide information beyond morphological changes in articular cartilage, with regards to early cartilage degeneration and biochemistry and further studies are clearly warranted.

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