Quantification of Focal Cartilage Lesions by T1ρ Magnetic Resonance Imaging

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Introduction: Focal lesions in articular cartilage are often associated with acute injuries such as ACL ruptures and meniscal tears. Arthroscopy is the gold standard for diagnosing focal chondral lesions, but it is limited due to its invasiveness and cost. MRI, the preferred imaging modality for soft tissue, has been proven to be effective for characterizing cartilage defect thickness and size. However, these conventional MR techniques are limited to visualizing gross morphological changes in cartilage. The current consensus claims that biochemical changes at the cartilage extracellular matrix—loss of proteoglycan content and disruption of the collagen network—precedes morphological changes. T1ρ relaxation time mapping, a quantitative MRI sequence, has been shown to be a potential marker of biochemical and biomechanical properties of cartilage. Previously we have shown in a case report the capability of T1ρ to detect focal lesions as seen in arthroscopy. The goal of this study was to quantitatively evaluate the capacity for T1ρ to quantify focal lesions in cartilage as validated by arthroscopy as a standard of reference.

Materials and Methods: Knee images were acquired from nine healthy controls and eight patients with focal cartilage lesions (ages 21 to 48, mean=35) on a 3T GE MR scanner using a quadrature knee coil. The focal lesions were identified retrospectively by an orthopaedic surgeon based on arthroscopic evaluation, and scored using the Outerbridge classification system which characterizes cartilage softening, fibrillation, and thinning on a scale of 0 to 4, according to increasing severity. Full thickness lesions (Outerbridge score = 4) were not included where bone is exposed as there was no cartilage T1rho for evaluation.

The acquisition parameters for the T1ρ-weighted imaging sequence were: TR/TE = 9,3/3.7 ms; FOV = 14 cm, matrix = 256 x 192, slice thickness = 3 mm, BW = 31.25 kHz, views per segment = 48, time of recovery = 1.5 s, time of spin-lock = 0, 10, 40, 80 ms, frequency of spin-lock = 500 Hz. The imaging protocol also included sagittal 3D water excitation high-resolution spoiled gradient-echo (SPGR) imaging and fat-saturated T2-weighted fast spin-echo (FSE) images.

Cartilage was segmented semiautomatically in sagittal SPGR images based on edge detection and Bezier splines, into five knee compartments, the medial and lateral femoral condyles (MFC and LFC), the medial and lateral tibia (MT and LT), and the patella. The T1ρ map was reconstructed by fitting the T1ρ-weighted images pixel-by-pixel to the equation S(TSL) α exp(-TSL/T1ρ).

The focal lesions were located on the FSE images by the surgeon and the regions of interest were subsequently superimposed onto the T1ρ maps. T1ρ values were calculated for the focal lesions and three general regions for comparison: the surrounding cartilage about the focal lesion, the overall cartilage of the patient, and the overall cartilage of controls. A paired t-test was used to differentiate between the four groups.

Results: The mean focal lesion T1ρ was significantly higher than the surrounding cartilage T1ρ in the same compartment (42.75 +/- 3.15 ms vs 39.12 +/- 3.47 ms, p=0.05). Compared to the overall patient cartilage, the focal lesions also showed higher T1ρ (42.75 +/- 3.15 ms vs. 40.20 +/- 2.09) but not significantly (p=0.09). Finally, the focal lesions T1ρ values were significantly higher than the control overall cartilage T1ρ values (42.75 +/- 3.15 ms vs. 38.94 +/- 1.37, p<0.05), proving the focal lesions regions show abnormal tissue.

Discussion: Preliminary results show increased T1ρ relaxation times in focal lesions in comparison to surrounding cartilage, overall patient cartilage, and overall control volunteer cartilage. T1ρ MRI mapping has the potential to interrogate cartilage focal lesion biochemical composition at an early stage of degeneration. Since focal lesions are early precursors to cartilage degeneration, notably osteoarthritis, future studies will follow patients longitudinally to probe changes in focal lesion T1ρ and evaluate its capability of determining prognosis. T1ρ mapping may be valuable tools of diagnosing and monitoring cartilage degeneration.


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