Ultra-short TE-enhanced T<sub>2</sub><sup>*</sup> mapping of cartilage

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**Background** This work explores the utility of ultra-short echo time (UTE) enhanced T<sub>2</sub><sup>*</sup> mapping to non-destructively probe articular cartilage structure, particularly the integrity of the collagen extra-cellular matrix. T<sub>2</sub><sup>*</sup> measurement built on UTE sequences (e.g., UTE-enhanced T<sub>2</sub><sup>*</sup> mapping) is sensitive to changes in short-T<sub>2</sub> signal (T<sub>2</sub> < 10 ms) and may provide improved sensitivity to subtle matrix alterations that are not well-captured by standard T<sub>2</sub> sequences<sup>1,2</sup>. Optical coherence tomography (OCT) is capable of non-destructively imaging articular cartilage at microscopic resolutions to detect structural changes within grossly normal appearing articular cartilage<sup>3-8</sup>. We hypothesize that high-resolution UTE-enhanced T<sub>2</sub><sup>*</sup> maps will discriminate between normal and abnormal collagen architecture as observed by OCT and polarized light microscopy (PLM).

**Methods** Ten osteochondral specimens from human tibial plateaus were collected post-mortem and from total knee replacement surgery, and were stored at -20°C before use. Explants were mounted on an acrylic plate with MRI lucent fiducial markers to allow precise spatial registration of study locations across imaging modalities. Quantitative T<sub>2</sub> and UTE-enhanced T<sub>2</sub><sup>*</sup> images were acquired on a clinical 3T MRI scanner (MAGNETOM Trio TIM 3T, Siemens Medical Solutions, Erlangen, Germany) using standard extremity coils (Invivo Inc., Gainesville, Florida, USA). A multislice coronal 2-D T<sub>2</sub> FSE sequence was acquired with seven echo images (TEs) ranging from 10-80 ms, repetition time (TR) 1800 ms, BW 326 Hz/pix, and 4 averages. The 20 2-D slices were collected with 417 x 417 µm in-plane resolution and 2 mm section thickness. Total T<sub>2</sub> scan time was 12 minutes. UTE-enhanced T<sub>2</sub><sup>*</sup> mapping images were acquired using a home-developed fast 3D UTE sequence named as AWSOS (acquisition-weighted stack of spirals)<sup>3</sup>. Eleven echo images, TE ranging 0.5 – 40 ms, were collected with resolution 391 x 391 µm in-plane, and 2 mm section thickness; FA/TR = 30°/100 ms. Scan time was 4.27 minutes per TE-image. T<sub>2</sub> values were lower and show a correlated to greater degree of cartilage degeneration<sup>3</sup>.

**Results** Osteochondral cores from human tibial plateaus were evaluated by microscopic OCT and histology and compared to corresponding regions of interest (ROIs) from T<sub>2</sub> and UTE-enhanced T<sub>2</sub><sup>*</sup> maps. Lower values were seen by T<sub>2</sub><sup>*</sup> compared to standard T<sub>2</sub> in the same section of tissue, and the two metrics exhibited different laminar patterns. UTE-enhanced imaging permitted T<sub>2</sub><sup>*</sup> mapping in the deep radial zone, a zone not detected by standard T<sub>2</sub>. Zonal stratifications observed on T<sub>2</sub><sup>*</sup> maps were similar to those observed within the collagen matrix arrangement seen by PLM. Focal T<sub>2</sub><sup>*</sup> lesions within the transitional zone corresponded to matrix derangement observed with PLM. OCT detected surface disruptions that could not be resolved by MRI and provided evidence for structural integrity and/or deficiency consistent with collagen organization seen by PLM. Example images from two ROIs on the same tibial plateau are shown in Figures 1-3.

**Discussion** Although standard T<sub>2</sub> is sensitive to water content and fragmentation of the collagen fibers occurring in cartilage degeneration<sup>1</sup>, long echo times (usually>10ms) used in standard T<sub>2</sub> prevent detection of short T<sub>2</sub> components, resulting in decreased overall sensitivity to subtle matrix alterations. UTE-enhanced T<sub>2</sub><sup>*</sup> mapping permits detection of short T<sub>2</sub> components such as those found in the deep radial zone. Results of this work suggest that T<sub>2</sub><sup>*</sup> mapping is also sensitive to focal derangements of the collagen matrix that are not obvious by standard T<sub>2</sub> mapping. Microscopic OCT and histology examinations of tissue sections with grossly different T<sub>2</sub><sup>*</sup> appearances demonstrate that UTE-enhanced T<sub>2</sub><sup>*</sup> mapping differentiates between normal and abnormal collagen architectures.


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