Variability of Meniscal T2* Calculations Using Ultra-Short Echo (UTE) Imaging

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Introduction. The knee meniscus is a highly ordered structure composed primarily of water (60-75%), proteoglycans (1-2% wet wt.) and collagen fibers (15-25% wet wt.) [1]. The isotropy of the tissue and limited water mobility results in a rapid dephasing of the signal during data acquisition. The normal meniscus displays low signal on standard clinical images, and meniscal pathology such as tears and degeneration leads to an increase of mobile water content producing sufficient signal for image interpretation. Direct visualization of the meniscus prior to tissue degeneration would be helpful. New magnetic resonance imaging (MRI) techniques use ultrashort echo times (UTE) (TE ~ 8-250μs) [2] to create sufficient contrast for direct visualization and quantitative T2* evaluation of the meniscus [3]. Currently, UTE scans are approximately 9-17 min in length [3,4]. It is necessary to minimize image acquisition time to make UTE imaging and subsequent T2* mapping feasible in a clinical setting. Reducing the image resolution is one method to reduce imaging time; however, it is unclear if changing the resolution will affect the resulting calculated T2* values. It is also uncertain how the selected echo times of the multi-echo images affect calculated T2* values. The purpose of this study was to evaluate the effects of image acquisition resolution and inter-echo times of a UTE pulse sequence on resulting calculated T2* values.

Materials and Methods. Intact, fresh-frozen adult sheep knees from another study were scanned. Image Acquisition: All scanning was performed using a 3T clinical MRI system and an 8-channel knee coil. Sagittal images were acquired at identical slice locations across the sheep meniscus during all phases of scanning to directly compare the effect of image acquisition parameters. Scan parameters were: TE: defined by user or scanner, TR: 350, flip angle: 45°, slice thickness: 3mm, FOV:12cm, BW: ±125 kHz, Freq: 512, Phase: defined by user, NEX: 2. First, a multi-slice *multi*-echo UTE sequence was used, with minimal TEs defined by the scanner: 0.3, 6.3, 12.5, 18.7 ms. The resolution of the acquisition was altered by varying the number arms of the radial sequence (Phase: 401, 801, 1201, 1601). Next, the timing of the echo images were varied for Phase=801.This phase value was selected since the length of the scan is clinically feasible (~9 min). Multi-slice *single*-echo images spanning different ranges of TEs were acquired. Three ranges of TEs were evaluated: Short TE: 0.3, 2.3, 4.3, 6.3 ms, Intermediate TE: 0.3, 4.4, 8.4, 12.5 ms, and Long TE: 0.3, 6.4, 12.6, 18.7 ms. Excitation parameters were kept identical for all image acquisitions. All scanning of an individual specimen required approximately 5 hours. Image Analysis: Custom written software (Matlab, Mathworks, Natick, MA USA) was used to calculate T2* values on a pixel-by-pixel basis by fitting the echo time to the corresponding signal intensity data using a monoexponential offset equation: $SI(TE) = So*\exp(-TE/T2^*)+C$. A bulk average T2* value was calculated from all pixels within a region of interest (ROI) and used for subsequent analysis. Statistical Analysis: A one-way repeated measures ANOVA was performed to determine the effect of image acquisition resolution on calculated T2* values. A second one-way repeated measures ANOVA was performed to evaluate differences of T2* due to range of TE used during imaging. Statistical significant was set at $p<0.05$. A Student-Newman-Keuls (SNK) post hoc test was performed when statistical significance was found.

Results. Data from a total of 13 ROIs from 2 sheep knees have been generated to date. The first ANOVA found a significant difference of T2* due to image acquisition resolution ($p<0.0001$). The T2* values of higher resolution images were significantly longer than the T2* values of lower resolution images (Fig. 1). The maximum T2* difference across all values of phase was 0.4±0.2ms (mean ± st.dev.). The second ANOVA found a significant difference of T2* due to the inter-echo spacing ($p<0.0001$). T2* values calculated from the multi-echo acquisition and long TE acquisition were similar and significantly longer than T2* values calculated from the short TE and intermediate TE acquisitions (Fig 2.). The maximum T2* difference across the varied TEs was 1.2±0.7 ms. A representative T2* map of the meniscus is shown in Figure 3.

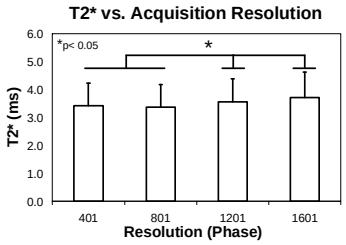

Figure 1. Higher resolution images had significantly longer T2* values than lower resolution images. Horizontal bars indicate statistical groupings from SNK analysis.

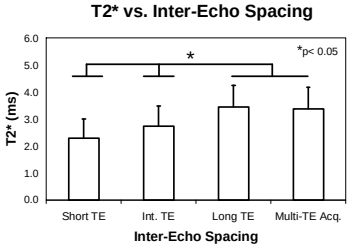

Figure 2. Longer inter-echo spacings resulted in significantly longer T2* values. Horizontal bars indicate statistical groupings from SNK analysis.

Discussion. Quantitative analysis of knee meniscus and highly ordered tissues is possible using the UTE pulse sequence. However, it is currently unknown how T2* measurement precision depends on input scan parameters. This study evaluated the effect of varying image resolution and inter-echo times of UTE images on the resulting T2* calculations. Higher resolution images had longer T2* values, but the maximum difference across the resolutions evaluated was less than 0.5 ms. The analysis also found T2* values from the multi-echo acquisition were similar to the T2* values from the single-echo long TE acquisition. We speculate that the effect of eddy currents on T2* values may be minimal when using multi-echo UTE acquisition. This study will aid in the development of optimal UTE scanning parameters for clinical investigation of the meniscus.

References

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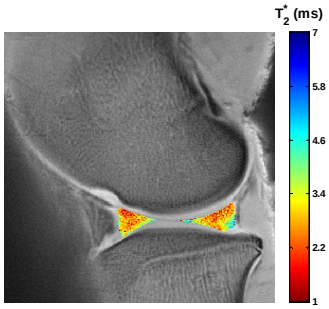

Figure 3. Representative T2 map of sheep meniscus, from a UTE image dataset.