Rapid 3D quantitative DESS T2 and T2* Mapping in the Meniscus

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Introduction: The role of the meniscus in knee degeneration and dysfunction is being increasingly recognized. However, detecting early meniscal degeneration with MRI, which is required to develop and evaluate disease modifying treatment strategies for osteoarthritis, has proven challenging. This is partially due to its highly organized collagen structure which leads to short T2 relaxation times. Imaging sequences, such as T2-prepared spoiled gradient echo and UTE, have shown that in vivo T2 and T2* range from 8-12 ms and 4-20 ms in healthy individuals, respectively. These quantities have also been shown to be indicators of early degeneration in the ACL injured population. Recently, 3D quantitative DESS (qDESS) has been shown to offer rapid mapping of T2 in articular cartilage. This work shows the feasibility of measuring meniscal T2 and T2* relaxation of the meniscus using 3D qDESS.

Methods: Five individuals (3 females, 29.2 ± 5.4 years, 74.0 ± 12.1 kg) with no history of knee injury were scanned following an IRB-approved protocol. Each participant underwent a series of sagittal scans on a 3T MRI scanner (Signa, HDxt, General Electric, Waukesha, Wisconsin, USA) using a 3-inch receive only surface coil positioned over the medial meniscus.

qDESS T2 maps were created using a protocol reported previously. Two DESS scans were acquired with differing diffusion weighting (scan 1: spoiler 1200 μG/cm in x, y, and z, FA 20°; scan 2: spoiler 4800 μG/cm in x, y, and z, FA=10°) and the following parameters TE1=2.4ms, TE2=14ms, TR=8.2, resolution=0.52mm, slice thickness=2mm, scan time=2.5min. T2 maps were created using ratios of signals from the four echoes, a signal model, B1 maps (to correct for field inhomogeneity), and custom software.

qDESS T2* maps were created by acquiring another two qDESS scans with differing first echo times (TE=2.4 and 3.4 ms, TR=10.4 ms, time=3.25 min) and the same parameters as above using the following equation: T2*= (TE2-TE1)/log(S1/S2) where TE1 and TE2 are the signals at the first echo of each scan. For validation of the T2* measurements, comparisons were made to maps created from a series of four 3D gradient echo scans (SPGR) with TE's of 4, 8, 12, and 20 ms, the same resolution as the qDESS T2* maps, and an imaging time of 4.5 min per scan.

For all scans, meniscal maps were created in the sagittal medial meniscal midslice through the anterior and posterior horns using custom software (Matlab, Mathworks, Natick, MA, USA). Mean and standard deviation of qDESS T2 and T2* maps were calculated. Differences between qDESS and SPGR T2* maps were expressed as the mean absolute T2* difference across volunteers the sagittal medial meniscal midslice.

Results: We successfully measured T2 and T2* in the meniscus using qDESS (Table 1, Figure 1 & 2) in five healthy volunteers. We observed good agreement between the qDESS and SPGR T2* maps; the mean absolute T2* difference between the maps across volunteers was 3.1 ± 0.7 ms. Since qDESS is a 3D sequence, T2 maps could be created in multiple planes (Figure 1).

Discussion: With qDESS, we can measure 3D T2 and T2* within one scan session, at high resolution, in multiple planes, and in short scan times. Measuring T2 and T2* simultaneously is useful because it allows for direct comparison of these quantities, which may provide different information in the meniscus due to its highly organized structure. The qDESS T2 and T2* maps were within the range of previously reported data (qDESS T2=10.5 ms vs. literature T2=8-12 ms; qDESS T2*=7.2 ms vs. literature T2*=4-20 ms). An advantage of the qDESS technique is the significantly shorter scan times than other techniques (10-20 min) with similarly high resolution, which is required since the meniscus is small. In the future, T2 and T2* measures can easily be combined into just two DESS acquisitions (total 6.5 min). The qDESS T2* mapping showed relatively good agreement with the conventional SPGR measurements; qDESS T2* maps created with 3 or more echoes may yield improved results. A similar comparison was not possible for T2 measured by 2D FSE due to the difficulty in acquiring sufficiently short echo times in a reasonable scan time.

Conclusion: We showed that with 3D qDESS it is feasible to simultaneously measure meniscal T2 and T2* relaxation in vivo in multiple planes, at high resolution, and with short scan times. 3D qDESS is a promising method for detecting early meniscal degeneration.