Preliminary Experience with dGEMRIC at 3.0 T

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Introduction: Delayed Gadolinium enhanced MRI of cartilage (dGEMRIC) has been proposed as a technique for molecular imaging of proteoglycan in cartilage [Invest Radiol 35, 622 (2000)]. Since loss of proteoglycans is an early step in the process of cartilage degradation, dGEMRIC is thought to be an early detector of arthritic changes allowing for potentially early therapeutic intervention. For the same reason, dGEMRIC can be used to monitor several disease modifying agents that are in the pipeline for testing in the clinic. The dGEMRIC technique involves intravenous injection of GdDTPA and T_1 imaging 90 minutes post-injection. To-date all of the reported work in the literature is based on dGEMRIC studies at 1.5 T. With the commercial availability of 3.0 T scanners, the higher field is being increasingly preferred for obtaining anatomical images of the cartilage, owing the higher signal-to-noise ratios (SNR). However, the feasibility of implementing dGEMRIC at 3.0T is not straightforward given the field dependency of the baseline T_1 of cartilage and the relaxivity of the GdDTPA used in the studies, and the larger chemical shift at that field strength. In this study, we have acquired data of normative T_1 values pre and post GdDTPA in cartilage using 2D approaches of T_1 imaging similar to those being currently used at 1.5 T.

Methods: Data were acquired on a 3.0 T GE Signa *VHi* (GE Medical Systems, Milwaukee, WI) using a commercial transmit/receive extremity coil. A 2D segmented FSE sequence (TR/TE/ETL = 2200/14 ms/5) with IR preparation was used to acquire T_1 weighted data with 5 different inversion times (100, 200, 500, 800, 2100 ms). Other acquisition parameters include: FOV = 16 cm, Matrix size: 256x256, Slice thickness = 3 mm, Bandwidth = +/- 32 kHz. A higher bandwidth compared to 1.5 T was chosen to minimize chemical shift artifacts.

T_1 mapping was performed with a custom software analysis routine based on MATLAB (The Mathworks; Natick, MA) using the following equation where M is the magnetization and α is the degree to which the 180° pulse really behaves as an inversion pulse: $\text{fit} = \text{abs}(M(1-2\cdot\alpha\cdot\exp(-TI/T_1)+\exp(-TR/T_1))$.

T_1 quantitation was obtained in phantoms consisting of plastic tubes containing 5 different concentrations of Gd-DTPA in distilled water (0.25, 0.5, 0.75,1, 2 mmol). Data were also obtained in 6 healthy subjects. For comparison data was also obtained on a 1.5 T GE Signa Twin Speed with Excite Technology (GE Medical Systems, Milwaukee, WI). The sequence was the same except for the TI values (50,150,350,650,1680). T_1 of the cartilage was measured within a region of interest of at least 100 pixels in the femoral condyle cartilage in the weight bearing region.

Results:

	T_1(ms) @ 3.0 T					T1(ms) @ 1.5 T				
[Gd-DTPA]	**0.25 mmol**	**0.5 mmol**	**0.75 mmol**	**1.0 mmol**	**2.0 mmol**	**0.25 mmol**	**0.5 mmol**	**0.75 mmol**	**1.0 mmol**	**2.0 mmol**
T1 (ms) in phantom	**704**	**397**	**273**	**208**	**109**	**678**	**394**	**273**	**207**	**104**
Data from asymptomatic subjects										
Cartilage no Gd	**1296 (n=1)**					**906 (same person on a different day)**				
Cartilage with Gd	**722±50 (n=5)**					**578 (n=1); 500 – 600 (several published previous data)**				
Data from 1 patient obtained at both field strengths on different days (~ 2 months apart)										
Cartilage with Gd	**469 (medial); 640 (lateral)**					**307 (medial); 484 (lateral)**				

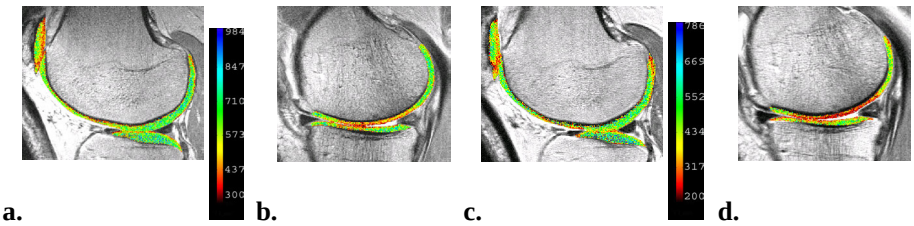

Figure 1: Images from one patient with arthritic changes in the medial femoral condyle obtained both at 1.5 T (c,d) and 3.0 T (a,b) on separate days. Note the decreased T_1 values observed at both field strengths in images b, d. (medial slice) compared to a, c (lateral slice). Also note the reduced conspicuity of the lesion at 3.0 T.

Discussion:

Both the pre-contrast and post-contrast T_1 values of cartilage at 3.0 T were found to be considerably longer compared to those at 1.5 T. This will have an impact on the choice of timing parameters for 3.0 T acquisitions for quantitating T_1 in dGEMRIC. The impact will be especially critical for 3D implementations of T1 imaging, which may be necessary for any longitudinal studies either to monitor disease progression or to follow drug efficacy. With the choice of parameters used in our protocol, the acquisition time for a 3D IR SPGR sequence with the longest TI (2100 ms), 512x512 matrix and 32 slices would be approximately 23 mins. Furthermore, the higher bandwidth used at 3.0 T to minimize chemical shift artifacts may compromise the inherent SNR advantage of 3.0 T over 1.5 T.

The relaxivity of GdDTPA in solution at 3.0 T (4.46 $s^{-1}mmol^{-1}$) is not very different from 1.5 T (4.68 $s^{-1}mmol^{-1}$), and is consistent with previous reports [MRM 46:955 (2001)]. However, recent work has shown that relaxivity in cartilage decreases with increasing field strength [MRM 48: 1068, (2002)]. Such a decrease in relaxivity could partially explain the apparent reduced lesion contrast seen on the 3.0 T images in Figure 1. However, some of the difference in this case could be due to a change in cartilage status over time, given the potential for dGEMRIC to change over a several month time frame.

In conclusion, the data presented here provide a framework with which to further pursue dGEMRIC studies at 3.0 T. The higher chemical shift and longer T_1s suggest that future implementation of dGEMRIC at higher field strength should incorporate efficient fat suppression such as spatial spectral pulses [JMRI 18: 66 (2003)], and any 3D implementations should consider faster T_1 mapping approaches such as Look-Locker technique [MRI 17:1163 (1999)]. The longer T_1s and the potential for less sensitivity of lesion detection at 3T might decrease the motivation for higher field for dGEMRIC, however the advantages of combining dGEMRIC with other studies at high field may over-ride this concern. Larger clinical studies will be needed to further investigate these issues.