Preliminary Experience with Fast T_1 Mapping for dGEMRIC using 3D Look-Locker Sequence

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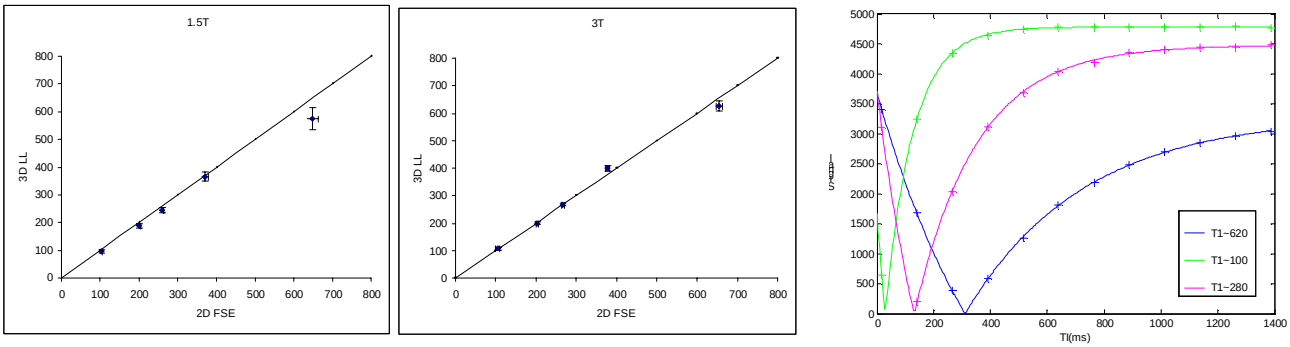
Introduction: Delayed Gadolinium Enhanced MRI of Cartilage (dGEMRIC) has been demonstrated as a technique for molecular imaging of proteoglycan in cartilage [*AJR* 2004;182:167]. The technique requires quantitative T_1 mapping to be performed 90 minutes post-injection of $GdDTPA^{2-}$. To date dGEMRIC studies have been reported using 2D acquisitions. In order to assess the distribution of disease over time and follow progression it would be desirable to implement a fast 3D T_1 mapping technique that allows full joint coverage in a reasonable acquisition time. Recently a 3D IR-SPGR technique that allows for images with 5 different TIs to be acquired in about 20 min was validated [submitted for publication]. In this study, we propose an alternate strategy based on the Look-Locker (LL) scheme [*Rev Sci Instrum* 1970; 41: 250] that can acquire data for 10 TIs at the same slice thickness and in-plane resolution during a single acquisition under 10 minutes.

Methods: Data were acquired on both 1.5T and 3.0T GE Signa short bore Twin speed systems (GE Healthcare, Milwaukee, WI) using a commercial transmit/receive extremity coil. For comparison, a 2D IR-FSE sequence was used, with different parameters at 1.5T (TR=1.8s, TI=1.68,0.65,0.35,0.18,0.05 s, TE = 8 ms) and at 3.0T (TR=2.2, TI = 2.1,0.8,0.5,0.3,0.1,0.05 s, TE =7.1ms). For segmentation purposes a 3D Fat Saturated FIESTA sequences was used. For all sequences (2D IR-FSE, the 3D LL and the 3D Fat Sat FIESTA) the following parameters were used: FOV = 16 cm, Slice Thickness = 3mm, Matrix Size = 256 x 256. The 3D LL sequence consists of a single adiabatic slab selective 180° pulse followed by multiple low flip angle excitation pulses to sample the longitudinal magnetization during its recovery. The T_1 recovery curve was sampled 10 times for each slice; the first TI was set to 20 ms. The subsequent TIs were given by (20 + TR · n · # slices, n =1 to 11). The time between two different 180° pulses was 2.2 seconds and for each 180° pulse the y phase encode was incremented. Centric phase ordering was used along slice direction. Other parameters for the sequence included 36 slices prescribed, 5° flip angle, TR = 4.8 ms, and bandwidth +/-62.5kHz. A 3D FatSat FIESTA (TR = 4.3 ms, TE = 1.5 ms, flip angle = 45º) sequence was run to allow easy segmentation of cartilage in the 3DLL images. T_1 mapping was performed with a custom software analysis routine written in MATLAB (The Mathworks; Natick, MA). The equation used for the fitting represents the acquired signal as: $S(t) = ABS(A - B \exp(-t(1/T_1 - \ln(\cos(\text{flip angle})/TR))$.

Phantoms consisting of plastic tubes containing different concentrations of $Gd\text{-}DTPA^{2-}$ in distilled water (0.25, 0.5, 0.75, 1, and 2 mmol) were used. Data were also obtained in three healthy subjects 90 mins after *iv* administration of $Gd\text{-}DTPA^{2-}$ (0.2 mmol/kg). Images of knees in the sagittal plane were acquired. For comparison of T_1 measurements by 3D LL, a single matched slice was acquired with the 2D IR-FSE sequence. Regions of interest of at least 100 pixels were defined in the central zone on the femoral condyles.

Results:



(a) (b) (c)

Figure 1 – T_1 measurements for the 3D LL *vs.* 2D IR-FSE in phantoms at 1.5 T (a) and 3.0 T (b). Error bars show standard deviation, the unity line shows good agreement between both measurements. (c) Illustration of representative LL data along with fitted data for three (of the five) phantoms with different T1s.

Based on ROIs defined in the central zone of the medial femoral condyles and tibial plateau, in the three non-symptomatic subjects the T_1 estimates by either technique (FSE *vs*. LL) was found to be statistically indistinguishable at either field strength (491±27 *vs*. 474±77, p = 0.56 @ 1.5 T; 621±75 *vs*. 571±63, p=0.11 @ 3.0 T).

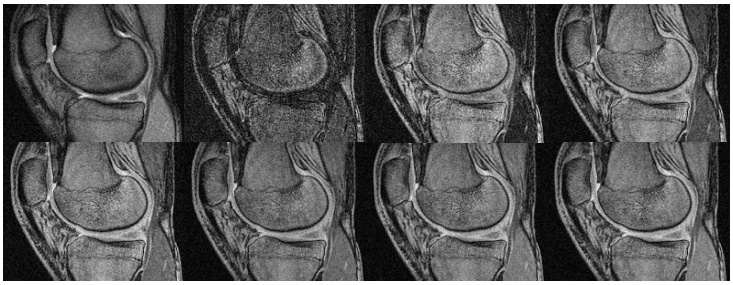


Figure 2 – Representative data set obtained in one subject (8 out of 10 TI images). Left to right TIs are: 20, 220, 421, 623, 824, 1026, 1228, 1429 ms.

Discussion: The 3D LL sequence presented here allows whole joint dGEMRIC coverage in about the same time as a 5 point single slice 2D IR-FSE acquisition with similar slice thickness and in-plane resolution. Preliminary data in phantoms show good agreement with 2D IR-FSE technique in terms of T_1 quantitation. *In vivo* data were of adequate SNR (38 @ 3.0T, 20 @ 1.5T for the image with the longest TI) to allow for T_1 mapping. Owing to the short TEs used for SPGR sequences, contrast between cartilage and fluid is not adequate for robust regions of interest definition. We used a position matched 3D FIESTA sequence with fat saturation to allow for regions of interest to be defined more effectively and also allow overlaying of the color maps on a high (cartilage-fluid) contrast anatomical template. It is conceivable that future LL implementations may be based on FIESTA acquisitions.

Conclusions: Of the sequences discussed here, the 3D Look Locker method clearly has best available efficiency of data acquisition. Also, acquiring the entire T_1 series during a single acquisition is advantageous over multiple acquisitions of other methods because of the need to make sure that gain settings are maintained between acquisitions. However, at this time 3D Look Locker is a custom research sequence. An alternate 3D T1 measurement implementation based on a standard IR-SPGR sequence with variable TR allows 3D data acquisition in about 20 min scan time. This standard implementation is important for widespread availability and especially for implementing multi-center trials with multiple vendor platforms. Nevertheless, establishing 3D Look-Locker feasibility should motivate vendors to implement for more widespread availability in the future. Preliminary data presented here strongly support the feasibility of using the time efficient 3D Look-Locker technique for dGEMRIC. Further optimizations such as flip angle, TR and slab profile of the alpha pulses etc. may further improve these results.

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