Comparison of 3D Look-Locker technique against 2D IR-FSE for dGEMRIC

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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 determine glyconsaminoglycan (GAG) level with joint cartilage. Most of the reported work on dGEMRIC has used 2D sequences to acquire single slice data for quantitative mapping. Since the limited single slice coverage presents several limitations, volume imaging is desirable for reliable comparison of cartilage damage in the full joint over time. A 3D inversion recovery spoiled gradient echo (IR-SPGR) sequence has been used for this purpose and has been shown to be effective, but the acquisition time is relatively long (~ 20 min) [JMRI 2006 24: 928]. A preliminary feasibility study with phantom and limited number of subjects [Invest Radio. 2006; 41:198] has demonstrated the feasibility of using a 3D look locker (3DLL) sequence for T_1 mapping. This study extends the findings in a larger number of subjects.

MATERIALS AND METHODS

Subjects: Thirty-one subjects, including 17 with self reported osteoarthritis (OA, 5 men and 12 women, aged 40-86, average age of 60.0 years) and 14 volunteers without OA symptoms (Controls, 5 men and 9 women, aged 18-40, average age of 29.2 years) were involved in this study. **Imaging:** Data were acquired on 1.5T GE Signa short bore Twin speed system (GE Healthcare, Milwaukee, WI) using a commercial transmit/receive extremity coil. A 2D IR-FSE sequence was used first as the reference (TR=1.8s, TI=1.68, 0.65, 0.35, 0.15, 0.05 s, TE = 7.4 ms, Matrix = 384x384), followed by 3DLL imaging. The 2D IR / 3DLL acquisitions were started at 80/92 (n=4), 103/120 (n=16), or120/135 min (n=11) post 0.2 mmol/kg Magnevist injection, respectively. The average difference in starting time between 2D IR and 3DLL acquisitions was 14.6 min. A 3D GRE (TR = 5.8 ms, TE = 2.1 ms, flip angle = 25°) sequence was used to define anatomy and hence allow for easy segmentation of cartilage in the 3DLL images. Images were acquired in sagittal plane with FOV of 16 cm and slice thickness of 3 mm for all 3 sequences. **3DLL sequence:** The 3DLL 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. Parameters for the sequence included 32 slices prescribed, 5° flip angle, τ=5.693 ms, bandwidth +/-62.5 kHz, and Matrix = 256x256. The T_1 recovery curve was sampled 11 times for each slice. The TIs were given by (20 + τ*(n-1)* # 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. The acquisition time is 9 min 24 sec. **Data analysis:** Since 2D IR sequence can only acquire single slice per acquisition but 3D LL allows acquire complete joint, 15 medial and 16 lateral condyles acquired with 2D technique were compared with matched slices of 3D LL images. ROIs for T1 mapping were defined in the central region of the femoral cartilage between the outer edges of the meniscus horns. T_1 mapping was performed with a custom software analysis routine written in MATLAB (The Mathworks; Natick, MA). A 3-parameter curve-fitting for T_1 was performed using the signal intensity equation used for standard inversion recovery sequence and corrected using $1/T_1 = 1/T_1^* + \ln(\cos(\alpha))/\tau$ where α=flip angle and τ =repetition time for the readout. Linear correlation, method of Bland-Altman, and paired t-test were used for data analysis.

RESULTS

T_1 values measured with the two techniques (479 ± 98 for 3DLL *vs.* 473 ± 101 for 2D IR, p=0.83) were found to be statistically in distinguishable.

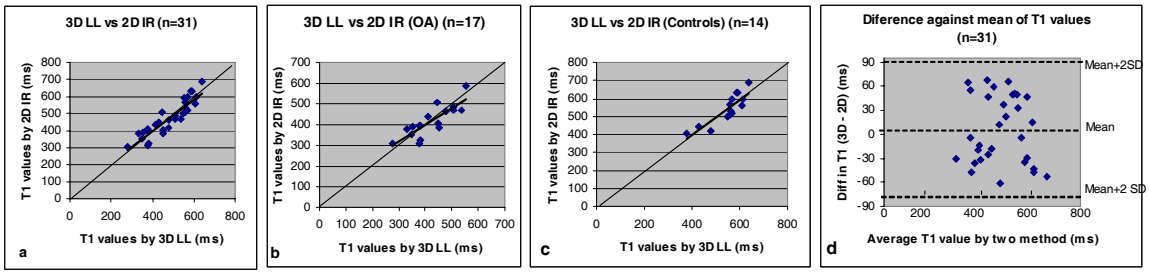

Figure 1. - T_1 values measured with the 3D LL *vs.* 2D IR-FSE in all subjects (a), subjects with OA (b), controls (c), and a plot of the difference between the methods against their mean for all subjects (d). There is a good agreement between the two techniques (a, d) with r value of 0.91. The correlation coefficient for controls (c) was only slightly higher (r=0.86) than in subjects with OA (b) (r=0.84).

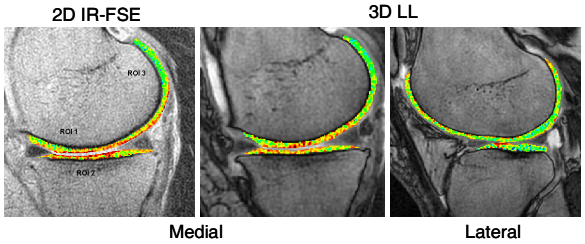

Figure 2. – Representative example of T_1 maps obtained in one subject with OA. Note the close agreement between the medial maps obtained by IR-FLSE and 3D LL methods. With 3D LL, we also have the lateral slice to evaluate.

Discussion and Conclusions: A major advantage of 3D LLT_1 mapping technique compared to single slice 2D technique for dGEMRIC is the ability to cover the entire joint in a comparable acquisition time (~ 10 mins). This is not a trivial advantage when considering the wash-in and wash-out kinetics of the contrast agent, especially in the diseased cartilage. When the 2D and 3D data acquisitions were separated by about 15 mins, the agreement was relatively good (r=0.91), but when separated by 30-45 mins (data not shown), the correlation coefficient reduced significantly to 0.44 in subjects with OA probably due to wash-in and wash-out kinetics.

On more practical terms, because the data for all TIs are acquired within a single acquisition, effect of subject motion between scans is minimized. Also, there is no need for the operator to consciously maintain the gain settings for acquisitions with different TIs. In this study, the in-plane resolution of 3D LL was lower than the 2D IR-FSE (630 *vs.* 420 micron). However, that is not a fundamental limitation of the technique. Further optimization of flip angle and TR (interval between inversion pulses) and alternate k-space sampling may allow for higher in-plane resolution.

Based on data to-date, it is clear that in majority of the subjects with OA, there is a significant disparity between the medial and lateral condyles in terms of T_1 distributions with an ionic contrast agent (Figure 2). This is consistent with the biomechanical basis for the disease progression. Ability to capture this information within a single acquisition of less than 10 mins may be desirable. The data presented here in larger number of subjects further supports the utility of 3DLL approach for dGEMRIC.

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