T1 quantification in the cartilage of the knee with a modified IR-FSE technique

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Introduction: T1 mapping in the cartilage offers a valuable diagnostic tool in degenerative disease of the cartilage. dGEMRIC protocol was suggested as a late contrast enhancement method to identify location of cartilage damage and severity of the disease [1]. Three dimensional Inversion Recovery Fast Spoiled Gradient Echo (IR-FSPGR) is widely accepted protocol for T1 mapping of the cartilage. In our study we investigated the feasibility and quality of an alternative acquisition technique that is based on 2D Inversion Recovery Fast Spin Echo (IR-FSE). The proposed sequence is a modified version of IR-FSE, where inversion and acquisition is consecutively performed on different slices without Inversion Time (TI) delay [2].

Methods: IR FSE is modified, with alternating inversion pulses and FSE acquisition blocks, where inversion and acquisition is acting on different slices. The sequence loop on slices is repeated with a shift between inverted and acquired slices. The actual inversion time on a given slice is determined by this shift. The minimum TI is produced with zero shift where inversion and acquisition is performed on the same slices. The maximum TI is produced with *shift = total number of slices*. Unlike in method described in [2], inversion recovery is used in order to maintain the full dynamic range for inversion recovery, and also in order to maintain the highest fidelity for 180° inversion. The inversion pulse is an adiabatic pulse, while the FSE acquisition block uses slice selective pulses. To evaluate the quality of the cartilage T1 mapping with the proposed technique, acquisition with IR-FSPGR and modified IR-FSE was performed on healthy volunteers. Post-processing and T1 map of the cartilage was generated and compared. Imaging was performed on a GE Signa 3.0T whole-body clinical scanner (General Electric Healthcare, Milwaukee, USA). Voxel-based mono-exponential curve fitting (T1 relaxation) was carried out on images with MATLAB (MathWorks, Natick, MA, USA).
The imaging parameters for modified IR-FSE were the following: Echo Train Length = 16, Repetition Time = 4592 ms, Echo Time = 17 ms, Field of View = 20 cm x 20 cm, Slice Thickness = 3 mm, Slice Spacing = 3 mm, Number of Excitations = 1. Total scan time was 9 minutes.
The imaging parameters for IR-FSPGR were the following: Flip Angle = 15°, Repetition Time = 4592 ms, Echo Time = 2.3 ms, Field of View = 20 cm x 20 cm, Slice Thickness = 3 mm, Slice Spacing = 3 mm, Number of Excitations = 1. Total scan time was 19 minutes.

Results:

Figure 1 shows a sagittal image of the knee of a healthy volunteer, acquired with the modified IR-FSE technique with false color T1 map of the cartilage. Figure 2 shows the knee of a healthy volunteer, acquired with variable TI IR-SPGR technique, also with T1 map. On the posterior location of the cartilage, T1 values (mean ± std.dev.) of 20 voxels for IR-FSPGR: T1 = 586 ± 71 ms; for modified IR-FSE: 636 ± 64 ms.

Discussion and conclusions: The advantages of the proposed sequence to the multiple echo IR-FSPGR technique are the following: 1. The method is a single acquisition technique, thus avoids problems due to slow patient motion. There is no need for image co-registration between images with different TI, furthermore the duration of acquisition of each image is identical. 2. The method is a Spin Echo based inversion recovery technique, thus less susceptible to B_1 inhomogeneity problems. 3. The technique offers faster acquisition, therefore promises higher resolution of the cartilage with the same acquisition time. The proposed method is two dimensional. This poses a problem if full 3D coverage is required. Due to the adiabatic inversion pulse, a gap between slices needs to be maintained in order to avoid cross talk effect. This gap can be optimized with an interleaved acquisition scheme; however, this potentially leads to problems of the repeated measurements. Our current work in progress focuses on optimization of the trade-off between the quality of inversion pulse and the required inter-slice gap. In the future we will investigate the feasibility of implementing double inversion blood suppression to minimize arterial blood flow artifacts.

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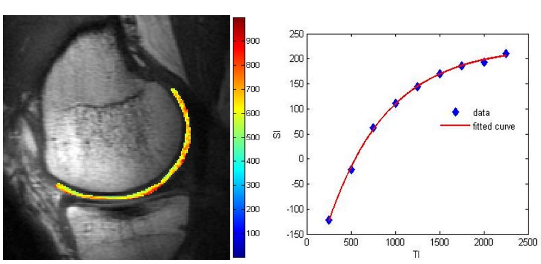
References

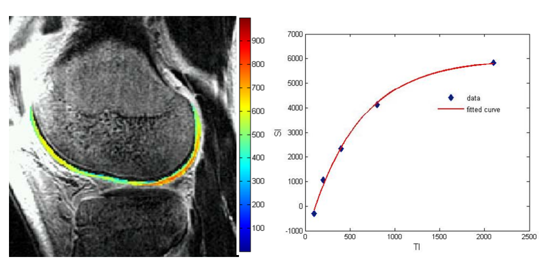
[1] C.A. McKenzie et al, JMRI 24:928–933 (2006); [2] J.B.M. Warntjes et al, MRM 57:528–537 (2007)

Figure 1.



Modified IR-FSE *inversion recovery*

Figure 2.



IR-FSPGR *inversion recovery*