Knee cartilage T1 mapping with High Resolution Multi Slice Inversion Recovery: feasibility, reproducibility and accuracy

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Introduction We propose and evaluate an alternative T1 mapping technique of the human knee cartilage allowing high resolution in a short time. Furthermore we propose a method for error estimation of the derived T1 values which is used to compute a weighted mean T1 over a region of interest. We demonstrate the acquisition and evaluation techniques in a reproducibility study on healthy volunteers and an osteoarthritis patient. As the cartilage is typically only 0-3 mm thin [1], and the typical voxel size in a conventional clinically feasible acquisition protocol is 0.45-0.60 mm [2,3], the number of voxels across cartilage thickness is only 1-6. In addition, the outermost layer of voxels can suffer from partial volume and motion effects, resulting in few voxels suitable for T1 analysis. In this work the commonly used inversion recovery spoiled gradient echo (IR-SPGR) sequence [4] is compared with a multislice IR sequence with fast spin echo readout (MSIR-FSE). With a multislice approach the dead time is shortened which reduces the total scantime. Moreover, MSIR-FSE can be used with parallel imaging readout (ARC), which reduces the scantime with a factor of 2. This provides the possibility to double the resolution in the same scantime, increasing the number of suitable cartilage voxels with a factor of 2.

Tabel 1: Scan parameters of the 4 protocols

Protocol	Inversion Times	FOV	Slice Thickness	Resolution	Inplane voxels	scantime
IR-SPGR	100,200,400,800,2100 ms	15x15cm	3mm	256x256	0.59x0.59mm	15 minutes
MSIR-FSE	370,611,1093,1574,2297 ms	15x15cm	3mm	256x256	0.59x0.59mm	7 minutes
MSIR-ARC	370,611,1093,1574,2297 ms	15x15cm	3mm	256x256	0.59x0.59mm	3.5 minutes
MSIR-HiRes	370,611,1093,1574,2297 ms	15x15cm	3mm	512x512	0.29x0.29mm	7 minutes

Materials and Methods One clinical osteoarthritis patient and two healthy volunteers were scanned twice on a 3T GE MRI scanner. Four protocols were applied: IR-SPGR, MSIR-FSE, MSIR-FSE with ARC (MSIR-ARC) and MSIR-FSE with ARC on High Resolution (MSIR-HiRes). The scan parameters are listed in table 1. To reduce motion artifacts the images were rigidly registered to the longest TI using a localized mutual information metric. One medial and one lateral slice were selected, and masks were drawn on three parts of the cartilage: the weight bearing and posterior femur, and the tibial plateau. T1 maps were calculated for each mask using a maximum likelihood estimator accounting for the Rician noise distribution in the MR magnitude images. Error maps were produced by computing the square root Cramer-Rao Lower Bounds, which provide a measure of uncertainty of the fit in ms. These were used to calculate a weighted mean in each mask, with a higher weight for voxels with a lower error.

Results Figure 1 shows the cartilage with MSIR-FSE and MSIR-HiRes, doubling the number of voxels. Figure 2 shows a scatterplot of the weighted means of the volunteer masks of MSIR-FSE versus both the MSIR-ARC and MSIR-HiRes. Figure 3 is an overlay of the calculated T1 map over both the IR-SPGR image and the MSIR-FSE image of the patient. In both images the arrows point to a region with lower T1 values, indicating cartilage damage. The range of the T1s is different, but both protocols show the same pattern. Further research is being performed to study the cause of this absolute difference in T1.

Conclusion MSIR-FSE and MSIR-HiRes are highly time-effective protocols for obtaining high resolution knee cartilage images which can be used to obtain reproducible T1 maps including error estimation.

(1) *Z. A. Cohen et al. Knee cartilage topography, thickness, and contact areas from MRI: in-vitro calibration and in-vivo measurements. Osteoarthritis and cartilage vol. 7, no. 1, 1999*

(2) *C. Siversson et al. Local Flip Angle Correction for Improved Volume T1-Quantification in Three-Dimensional dGEMRIC Using the Look-Locker Technique. Journal of Magnetic Resonance Imaging vol. 30, no. 4, 2009.*

(3) *C. Siversson, et al. Repeatability of T1-Quantification in dGEMRIC for Three Different Acquisition Techniques: Two-Dimensional Inversion Recovery, Three-Dimensional Look Locker, and Three-Dimensional Variable. Journal of Magnetic Resonance Imaging vol. 31, no. 5, 2010.*

(4) *C. McKenzie et al. Three-dimensional delayed gadolinium enhanced MRI of cartilage (dGEMRIC) at 1.5 T and 3.0 T, Journal of Magnetic Resonance Imaging vol. 24, no. 4, 2006.*

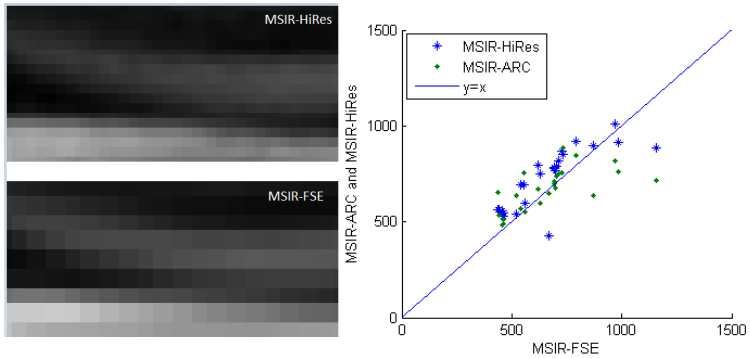

Figure 1 and 2: the difference in resolution between MSIR-FSE and MSIR-HiRes visualized by zooming into the cartilage (1) and a scatterplot of the MSIR-FSE vs MSIR-ARC and MSIR-HiRes (2)

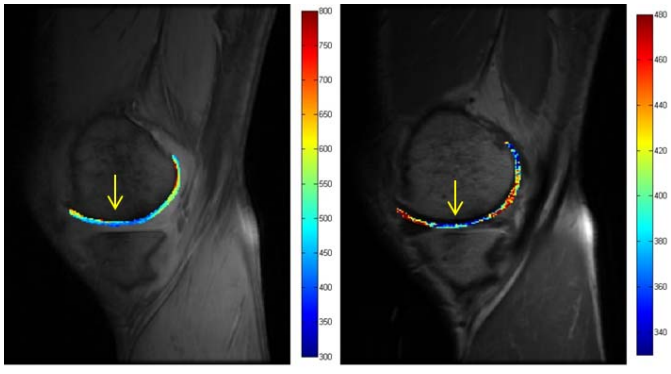

Figure 3: T1 map of the femoral cartilage as an overlay over the IR-SPGR (left) and MSIR-FSE (right). The same pathology pattern is visible in both images, although the T1 range is different