Rapid 3D-T₁ Mapping of Cartilage with Parallel Imaging at 3.0T

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Purpose: The objective of this work was to rapidly acquire T₁-weighted images using a three-dimensional fast low angle shot (3D FLASH) sequence in combination with generalized auto-calibrating partially parallel acquisitions (GRAPPA) and variable-flip-angle (VFA) method at 3.0T.

Methods: 3D T₁ maps of model systems (Gd and agarose phantoms), bovine cartilage, and human subjects were constructed on a 3.0T clinical wholebody MR scanner (Magnetom Tim Trio, Siemens Medical Solutions, Erlangen, Germany) employing a phased-array (PA) knee coil (18 cm diameter, 8-channel transmit/receive). The T₁ values of model systems measured using the 2D inversion-recovery fast-spin-echo (IR-FSE) sequence were considered as reference method to validate the rapid 3D method for comparison. Then the rapid 3D-T₁ mapping method was applied to 3 healthy (n=3 males, mean age ±26 years) and 2 clinically diagnosed OA subjects (1 male, 1 female, mean age ±50 years). Global and regional T₁ of patellar, femoral and tibial cartilage were analyzed and compared with that of conventional reference method (without parallel imaging). Total scan time to acquire a whole knee joint (FOV=13cm, NEX=2, slices=112; TR/TE=15ms/6.5ms) with 0.7mm³ isotropic resolution was ~5 minutes with parallel imaging (acceleration factor 2). The reproducibility of the rapid 3D-T₁ maps was quantified using coefficient of variation (CV) and a non-parametric rank test (Wilcoxon signed rank test) to determine whether there were any statistically significant differences between median T₁ with different acquisition schemes.

Results: 3D-T₁ maps of the phantom were constructed using PA-coil with iPAT1, iPAT2, iPAT3, and iPAT4. CV of the median T₁ of the phantom across different acquisition schemes was 6.22%. The standard deviation of the median T₁ of femoral, tibial, patellar cartilages, and the average across different acquisition schemes was observed to be between 14.65-45.58ms, 42.84-72.73ms, 85.64-108.73ms, and 38.54-70.04ms respectively across the subjects. RMS-CV of median T₁ of femoral, tibial, patellar cartilages, and the average among the subjects was between 7.51-9.85, 7.25-9.90, 8.20-11.09, and 7.61-8.50 respectively. The differences between the median T₁ acquired with different methods were statistically insignificant for all the analyzed cartilages (P>0.05). In current study, rapid 3D-T₁ mapping with VFA and parallel imaging with different acceleration factors (AFs 1, 2, 3, and 4) seems to have no obvious influence on the T₁ mapping (before and after contrast agent administration).

Conclusions: The preliminary results demonstrate that the rapid 3D-T₁ mapping obtained using VFA with parallel imaging are highly reproducible in an agarose phantom and in human knee joint in vivo. It is possible to quantify 3D-T₁ mapping of whole knee joint (with 0.7mm³ isotropic resolution) under ~5 minutes with excellent in vivo reproducibility at 3.0T.