In Vivo Human Brain Diffusion Tensor Imaging (DTI) at 3T and 7 T

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Introduction:

Higher B_0 fields are expected to optimize fiber tracking and to increase the signal-to-noise ratio which should lead to higher spatial resolution of DTI [1,2]. However, at high fields B_1 inhomogeneities are strong and result in sever distortions and signal voids in DTI. The B1 inhomogeneity results in ill-defined pulse angles that vary considerably over the probe volume. Parallel imaging enables DTI with reduced distortions and high spatial resolution [3-5]. We applied parallel imaging combined with data post-processing to acquire high resolution in vivo DTI at 3T and 7T.

Methods:

DTI was performed on (3) a 3T whole body scanner (Trio, SIEMENS, Germany, IDEA VA25A), gradients 40mT/m, 8 element phase array (PA) coil (Siemens); (4) a 7T whole body scanner (SIEMENS, IDEA VB12T), gradients 38mT/m, 8-element PA coil (RAPID, Würzburg). Parameters of the diffusion-weighted SE-EPI sequences were for 3T: TR/TE=10000/98, BW=1132 Hz/Pixel, 30 SL à 3mm, 192x144 interpolated to 192x192, GRAPPA factor 3, b-factors=0, 800 s/mm², 12 different gradient directions; for 7T: TR/TE= 9000/92 ms, BW= 1370 Hz/Pixel, 10 SL à 3mm, 192x144 interpolated to 192x192, GRAPPA factor 3, b-factors=0, 800 s/mm², 12 different gradient directions. A slow frequency change during the measurement led to an apparent shift between successive images which prohibited averaging during the measurement. Hence, data were acquired as single acquisitions, transferred to an external PC, registered and averaged. Calculation of diffusion tensors and fiber tracking were performed using the public domain tool FSL [6]. A home-built tool which parallelizes FSL accelerated the calculation on a 10 PC GRID cluster. Nearly the same starting maps and waypoint maps to track the fibers were used to ensure the comparability of the results at 3T and 7T.

Results:

Parallel imaging led to a significantly increased image quality due to reduced distortions and decreased TE [4,5] (i.e., higher signal-to-noise ratio). Comparing exemplary results of the same volunteer, examined at 3T and 7T, showed excellent DT images at 3T for almost the complete brain except for some minor susceptibility artefacts near the skull base (fig. 1). Different white matter tracts could be determined. At 7T, the DT image quality was similar except for some susceptibility artefacts near the skull base and some signal voids due to the B1 inhomogeneity. Averaging ameliorated these voids, so that the resulting ADC-maps [7-9] could serve well for fiber tracking of the larger white matter tracts.

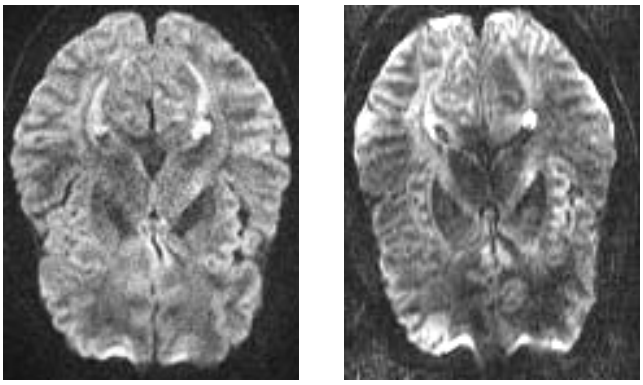

Fig. 1: Diffusion-weighted image (b=800 s/mm^2), 4 averages, same volunteer; ***left:*** DTI at 3T; ***right:*** DTI at 7T

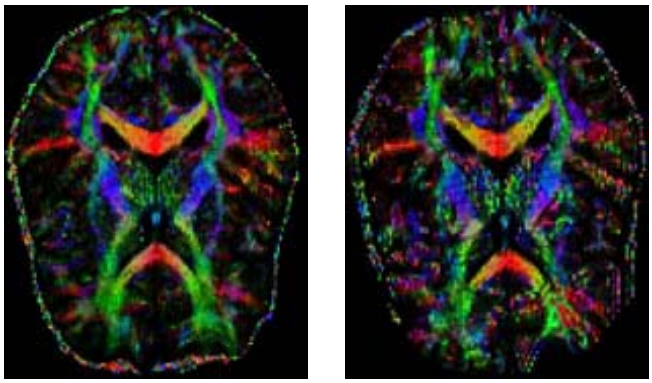

Fig. 2: color coded vector map (x-direction → red, y-direction → green, z-direction → blue) modulated with anisotropy map, same volunteer; ***left:*** at 3T; ***right:*** at 7T

Conclusion:

DTI is feasible even at ultrahigh fields of up to 7T but requires parallel imaging. No significant differences between GRAPPA and SENSE reconstruction were detected. Fibertracking at both 3T and 7T obtained reliable and comparable results for the larger white matter tracts. Improving DTI, phase array coils with more elements, sequence optimisation with respect to shorter TE, optimized pulses, and stronger gradients will be advantageous.

References:

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