Diffusion Tensor Imaging at 7T: Expectations vs. Reality Check

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INTRODUCTION

Diffusion tensor imaging (DTI or HARDI) offers the unique possibility to detect brain microstructure *in vivo*. However, diffusion weighting requires strong and long gradient pulses that, in addition to strong T_2 weighting, reduce the signal significantly to encode the directional information. Therefore, DTI is notoriously SNR hungry and the use of very high field strength has been proposed to increase sensitivity. Despite the introduction of 7T, it is still not clear from first demonstrations if 7T results in data quality improvement [1].
In this study, the SNR gain in DTI measurements at 7T is estimated based on realistic tissue and imaging parameters. In addition, large volume coverage DTI data have been acquired at 3T and at 7T and were compared.

MATERIALS AND METHODS

DTI data were acquired at 3T and 7T (Siemens) with similar gradient hardware. 8-channel (3T) and 24-channel (7T) head coils were used. Diffusion encoding used a double Hahn spin echo to compensate for eddy currents. Image readout was performed using EPI with parameters previously optimized separately for each field strength (both: 1.9 mm isotropic, 35 slices, b = 800, 12 directions, 4 averages; 3T: TE 80 ms, matrix 128, bandwidth 1955 Hz/px, R = 2; 7T: TE 77 ms, matrix 112, bandwidth 1540 Hz/px, R = 3). The 3T and 7T data were co-registered and processed in SPM5. A simplified estimate of the achievable SNR gain is based on the difference in field strength (magnetization), bandwidth, reduction factor, echo time, and T_2:

$$SNR_{gain} = \frac{7}{3}\sqrt{\frac{BW_{3T}R_{3T}}{BW_{7T}R_{7T}}}\frac{matrix_{7T}}{matrix_{3T}}\exp\left(\frac{TE_{3T}}{T_{2,3T}}-\frac{TE_{7T}}{T_{2,7T}}\right) .$$

RESULTS

The data quality allowed for estimation of diffusion tensor Eigen values, vectors, and FA maps at both field strengths. These maps are qualitatively very similar. The image SNR in the b = 0 data is 115 and 98 (gray matter) and 67 and 57 (white matter) for 3T and 7T respectively. Correspondingly, the diffusion direction maps are slightly cleaner at 3T. T_2 values for 3T and 7T were taken from previous studies [2]. The Hahn spin echo T_2 for brain tissue was determined to be approx. 75 ms for 3T and 45 ms for 7T. Thus, the estimated SNR gain from 3T to 7T is 4.5% based on the equation above. The experimental data show an SNR loss of about 15% at 7T compared to 3T.

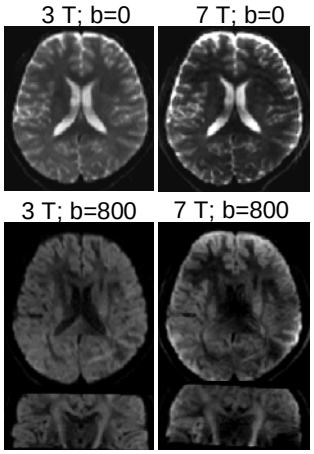

Fig. 1: Original EPI data showing the increased T_2 weighting at 7T.

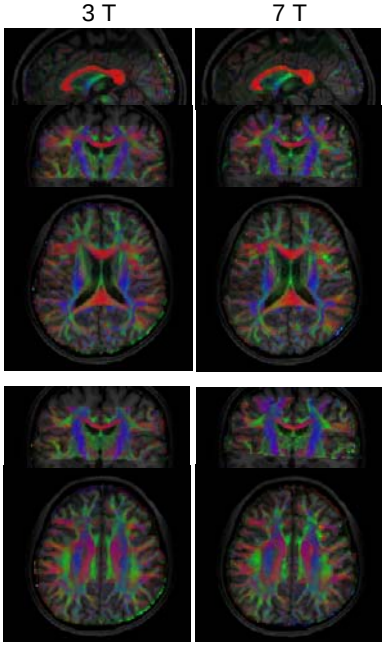

Fig. 2: Diffusion tensor data showing the main diffusion direction at different levels in the brain. 3T and 7T data are very similar with a slightly cleaner appearance at 3T.

DISCUSSION

Large FOV DTI at 7T is possible with good homogeneity. T_2-weighting is significantly stronger at 7T despite shorter echo times. For the long diffusion encoding time needed with whole body gradients, significant T_2-decay occurs. This decay is accelerated at 7T due to the reduced T_2 compared to 3T. Thus most of the SNR advantage is lost. The discrepancy between the SNR estimate and the experimental data may be due to different g-factors or B1 inhomogeneities that have not been included in the calculation. Using current whole body gradient systems, at best a very minor improvement in diffusion imaging can be expected at 7 Tesla. This comparison will be even less favorable for 7T when larger b-values are employed, leading to longer echo times with stronger signal penalty at higher field. The full potential of very high field DTI may therefore only be realized if significantly stronger gradient systems such as local head gradients are used. Of course, lower field strength acquisitions will also benefit from such gradients but to a smaller amount.

Acknowledgement
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REFERENCES

[1] Luetzkendorf et al. ISMRM 2008, 1812
[2] Cox, Gowland, ISMRM 2008: 1411