Optimized EPI-DTI and TSE-DTI at 3 T and 7 T in the Brain

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Background

Diffusion tensor imaging (DTI) and its higher-order variants are valuable clinical tools, providing detailed information on brain microstructure. Their processing requires high SNR, so high field MRI (7 T) can potentially be harnessed for higher sensitivity or resolution. *In vivo* diffusion imaging with the standard single-shot echo-planar imaging (EPI) or less common turbo-spin echo (TSE) avoids intershot phase inconsistencies. However, EPI suffers from susceptibility-induced artifacts, while TSE can suffer from T_2 blurring and multiple echo pathway interferences. *In vivo* 7 T EPI-DTI has included highly parallel imaging [1-8], field map dewarping [4], phase encode reversals [6], and RF pulse variations [6] to optimize image quality. Since high field effects are manifold (SNR, relaxation, parallel imaging, distortions) [9], cross-validation studies of available diffusion sequences are needed to optimize a given application. This work presents EPI- and TSE-DTI in healthy volunteers at 3 T and 7 T.

Methods

Imaging used Siemens 3 T TIM Trio (12-ch head coil) and a full body 7 T scanners (volume Tx/24-ch Rx head coil, Nova Medical). N =16 healthy volunteer scans were performed. EPI-DTI used a twice refocused spin echo with bipolar diffusion gradients (TRSE-BPG) and echo-planar readout. TSE-DTI used a modified sequence with TRSE-BPG preparation and centric ordered TSE readout with displacement gradients to isolate signal parity [10]. EPI/TSE-DTI used 2x2x3 mm resolution, b=0,500,1000 s/mm^2, 6 diffusion directions. 'Targeted' TSE-DTI at 7 T used 1.3x1.3x3 mm resolution and b=0, 1000 s/mm^2. Other typical parameters are listed in Table 1. Additional processing: **EPI** (7T)**:** separate averages (2 ea.) were acquired with different phase encode polarities (A→P and P→A). Field map corrections of each set (FSL software) were performed. **TSE** (3T, 7T)**:** T_2 maps from a multiple spin echo sequence were used to locally reduce T_2 blurring via Wiener filter k-space deconvolution [8]. Total histograms of mean diffusivity (MD) and fractional anisotropy (FA) were generated for matched EPI and TSE slice groups (w/ and w/o deblurring correction).

Scan	N	TR / TE (ms)	Avgs.	R	Slices	TA (min)
EPI 3T	4	5750 / 86	3	2	36	4
TSE 3T	4	1000 / 105	4	2	28	25
EPI 7T	4	5900 / 90	4	3	22	5
TSE 7T	3	3640 / 107	3	2	9	18
TSE 7T	1	4560 / 105	8	2	2	9

Table 1: Scan parameters. TSE:TR=repeat time/slice, EPI:TR=total repeat time. TA=acquisition time; N = subjects; R = GRAPPA factor.

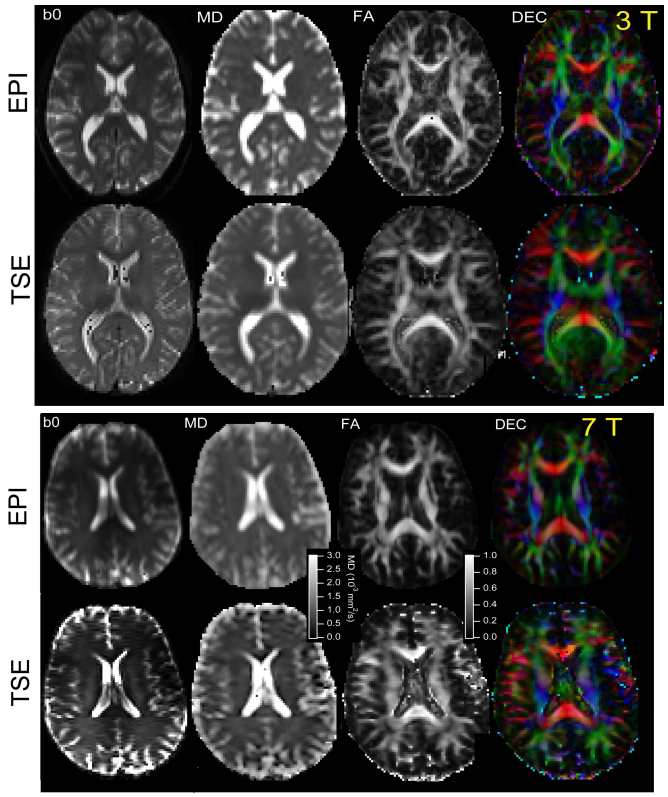

Figure 1. EPI- and TSE-DTI example results at 3 T and 7 T. b0 : unweighted image. MD: mean diffusivity. FA: fractional anisotropy. DEC: direction encoded colormap. Signal averages (3 T EPI / 3 T TSE / 7 T EPI / 7 T TSE) were (3 / 10 / 4 / 3).

Results: Figure 1 shows example images at 3 T and 7 T for both EPI and TSE sequences. Results of high quality and consistency are obtained for the full DTI dataset. Quantitative agreement is shown in Figure 2; total TSE histograms and their 1st and 2nd moments all more closely agree with the EPI standard with the deblurring correction. Finally, in a "targeted" TSE-DTI 7 T acquisition (Figure 3), high resolution results in complex areas like the pons or subcortical white matter can be obtained *without* susceptibility distortions.

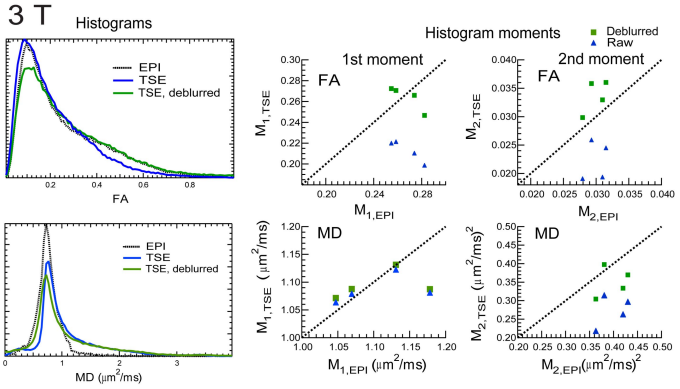

Figure 2: Left : Example 3 T MD, FA histograms from EPI, TSE and deblurred TSE. Right: Histogram moments for 4 subjects.

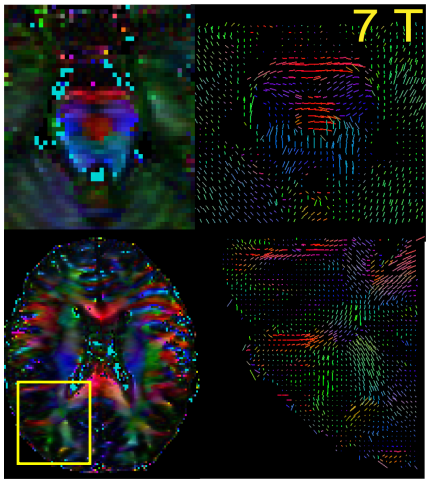

Figure 3: Targeted high resolution (1.3 mm) TSE-DTI at 7 T in the pons and midbrain. Left: DEC colormap. Right: primary diffusion eigenvectors.

Discussion

With a combination of parallel imaging and correction algorithms, both EPI and TSE deliver equivalent DTI results at moderate resolution (2 mm) at both 3 T and 7 T, providing strong validation of both sequences. Though less temporally efficient, due in part to specific absorption rate (SAR) limitations, TSE also allows higher resolution in targeted acquisitions in complex anatomies. Cutting edge techniques such as parallel transmission [11] are expected to enhance such targeted acquisitions in the future without the distortion penalties of traditional EPI.

References

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