Effects of Multichannel Transmission on DTI Metrics

G. Guangqiang[1], R. Henry[2], and C. Rae[1,3]
[1]Neuroscience Research Australia, Sydney, NSW, Australia, [2]Departments of Radiology and Biomedical Imaging, Neurology, and Bioengineering Graduate Group, University of California, San Francisco, United States, [3]UNSW, Sydney, Australia

Introduction

Magnetic resonance imaging (MRI) with multi-channel transmission of radiofrequency (RF) applies multiple RF pulses simultaneously to achieve a spatially more homogeneous excitation compared to single channel RF [1]. Multi-transmission of RF also improves the signal-to-noise ratio (SNR) and reduces specific absorption rate (SAR) [1]. This is crucial for MRI acquisitions to achieve less uncertainty induced both by inhomogeneous RF excitation itself as well as its complication of random noise. Also, a homogeneous RF excitation would benefit imaging methodologies sensitive to noise such as diffusion tensor imaging (DTI), which measures anisotropic water molecular diffusion through diffusion encoded MRI pulse sequences and has been applied in particular mapping the white matter fibres in the brain [2]. Measurements for the reduction of uncertainty with the multi-transmission of RF, however, have not been conducted for DTI. In order to verify the improved imaging performance with the multi-transmission of RF, we quantify the uncertainty of DTI measurements for anisotropy through statistical analysis of human brain data.

Methods

Five healthy volunteers age from 24 to 40 year old were scanned on a Philips Achieva 3T scanner (Philips, Best, The Netherlands) with an 8-channel head coil. DTI was acquired using a single-shot spin-echo EPI sequence with a b-value of 1000s/mm^2 along 32 directions together with a B0 image. The field of view was 240 x 240 mm, and the matrix size was 96 x 96 x 55 for the whole brain. The voxel size was 2.5 mm isotropic, and the TR and TE were 11.3 s and 8.3 ms respectively. For each subject, two DTI datasets were acquired without and with multi-transmission respectively. Receiving SENSE with a reduction factor of 2 was applied in both cases. The order of acquisition was randomized to minimize motion effects, which was further reduced through registering each diffusion weighted volume (DWI) to the B0 image using FLIRT (FMRIB's Linear Image Registration Tool, Oxford, UK) [3] with a sinc interpolation full-width of seven voxels [4]. Diffusion tensors were reconstructed through linear regression, and fractional anisotropy (FA) was then calculated [5]. A residual bootstrap [5] with 200 repetitions of resampling was used to estimate the uncertainties as measured by the standard error (SE) of FA. For the group analysis, the FA maps were firstly registered to MNI space. The transformation was estimated through applying a linear registration of B0 image to the MNI template with FLIRT, and the FA maps were registered with the same transformation. Non-linear registration was then conducted using FNIRT with an arbitrarily chosen FA map of a subject as the template. The same transformations were applied on the SE of FA maps, and the coefficient of variance (CV), which is the ratio between the SE and mean, was calculated as a normalized measure for the uncertainty.

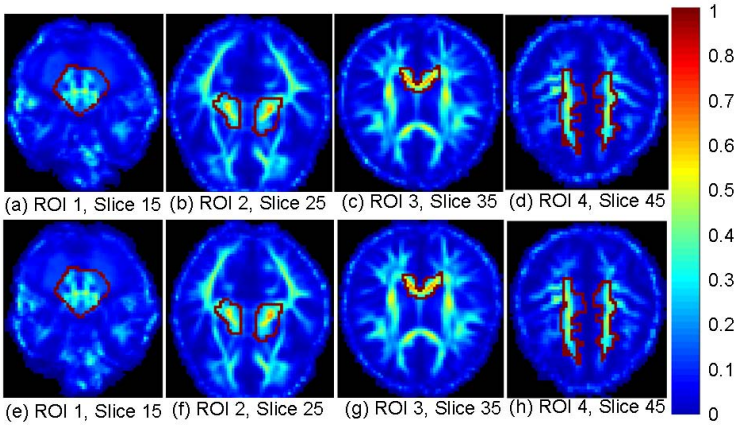

Figure 1: Averaged FA map with ROI. (a)-(d) for non-Tx, (e) –(h) for Tx.

Results and Discussion

Four regions of interests (ROI) (Fig. 1) with high SE were drawn in different slices across the whole brain. The mean FA, SE of FA and CV (Table 1) over all subjects were shown with standard deviations (SD) for each ROI. The mean SE of FA and CV were lower with multi-transmission (Tx) in every ROI as well as in all white matter (WM) voxels (FA > 0.2) compared to without multi-transmission (Non-Tx). Particularly, there was a reduction of SE between 2.74% and 7.04% in every ROI, and the CV was reduced between 1.57% and 8.49%. Also, the SE with multi-transmission was reduced for 3.46% with a CV reduction of 1.04% over all WM voxels. The scan time and SAR were 6 min 54 sec and less than 36% respectively both for with and without multi-transmission. The less uncertainty as measured by the SE of FA and CV indicates improved reliability of DTI measurements with multi-transmission of RF given the same scan time and SAR.

		ROI 1	ROI 2	ROI 3	ROI 4	WM
FA (x10^{-1})	Non-Tx	2.63±1.07	3.39±1.42	4.07±1.77	2.87±1.51	2.24±1.17
	Tx	2.62±1.07	3.41±1.43	4.05±1.79	2.84±1.51	2.22±1.16
	% diff.	**0.38%**	**0.59%**	**0.49%**	**1.05%**	**0.89%**
SE of FA (x10^{-2})	Non-Tx	1.74 ± 0.48	2.70±0.10	1.59±0.32	1.46±0.33	2.31±2.76
	Tx	1.66 ± 0.46	2.51±0.09	1.54±0.37	1.42±0.33	2.23±2.58
	% diff.	**4.60%**	**7.04%**	**3.14%**	**2.74%**	**3.46%**
CV (x10^{-2})	Non-Tx	7.48 ± 3.12	9.42±5.18	5.11±3.25	6.88±4.24	11.49±12.49
	Tx	7.13 ± 2.78	8.62±4.54	5.03±3.25	6.70±4.11	11.37±12.18
	% diff.	**4.68%**	**8.49%**	**1.57%**	**2.62%**	**1.04%**

Table 1: FA, SE of FA and CV for Non-Tx and Tx
(% diff. was calculated with Non-Tx results as 100%).

Conclusions

We quantified the uncertainty in DTI measurements for FA with multi-transmission of RF pulses. The uncertainties of DTI results were consistently lower across subjects and ROI with multi-transmission compared to single channel transmission of RF. We proved that multi-transmission of RF improved the reliability of DTI measurements. This will potentially reduce the necessary scan time through increased SENSE factor and reduce SAR while maintaining the reliability of DTI measurements. Moreover, DTI studies with multi-transmission of RF have a bigger effect size with the same probability due to lower SE. That is statistical analysis of DTI measures such as FA acquired with multi-transmission may require fewer repetitions of scans and fewer subjects to find significant results.

References

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