Automatic Correction For Signal Intensity Drift In Diffusion Weighted Images

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Purpose

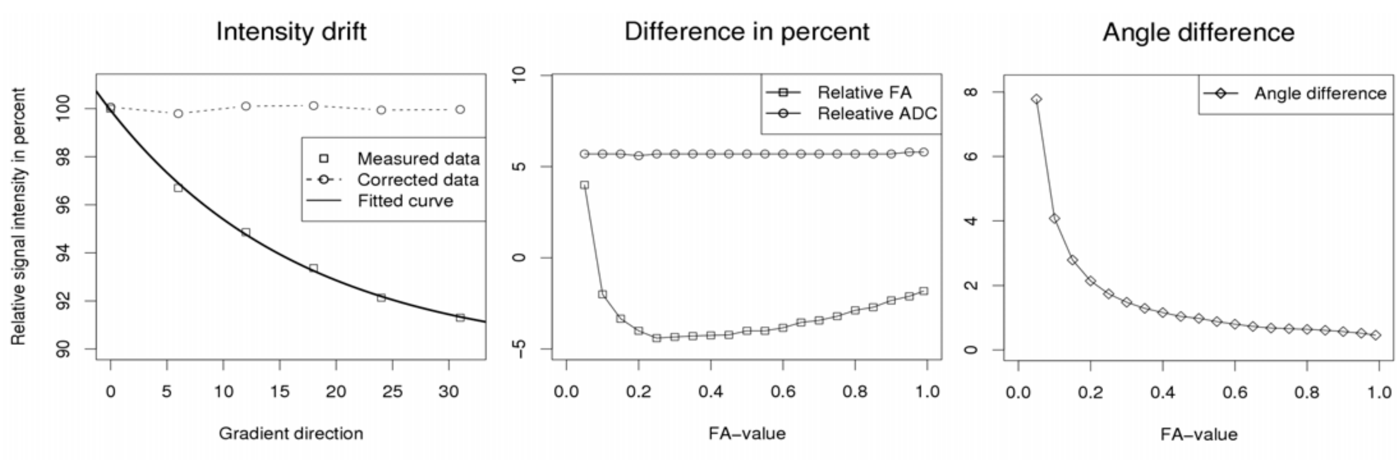
To develop an automatic method to correct for the intensity drift which may occur when performing Diffusion Tensor Imaging (DTI) [1] under full duty cycle. Furthermore we wish to quantify the effect of intensity drift on DTI data using simulation.

Introduction

We noticed that the average signal intensity decreased for each gradient direction when performing diffusion weighted scanning on a spectroscopy water phantom. This behavior was also verified for human data. The drift is probably due to heating caused by the combined application of diffusion encoding gradients and high bandwidth EPI read-out. Thus, the diffusion weighted images will be increasingly underestimated in a conventional DTI sequence, where the unweighted images are acquired first. Consequently this causes overestimation of the Apparently Diffusion Coefficient (ADC) values. Also, we assessed the impact on the estimation of Fractional Anisotropy (FA) and the primary diffusion direction used a number of tractography algorithms, such as FACT [2].

Methods

DTI was performed on a spectroscopy water phantom using a 8-channel head coil and 3.0 T GE Medical Systems scanner with a 40 mT/m gradient system. DTI was performed using single shot double spin echo EPI (DSE-EPI) due to it lower sensitivity to the eddy-currents [3]. The diffusion encoding scheme consisted of a scheme with 26 different gradient directions isotropically distributed in space, b-factor of 1000 s/mm^2. The scheme was modified by adding an unweighted gradient direction (b-factor=0 s/mm^2) for each 5 to 6 weighted gradient direction, in total six unweighted gradients were added. The maximum gradient strength was kept at 36 mT/m. 58 slices locations of slice thickness 3.00 mm were acquired, covering a 24 cm FOV in a 256 by 256 matrix. TR/TE = 17000/71 ms. A total of 4 replicated scans were performed, acquisition time was 36 minutes. For each unweighted gradient direction all voxels belonging to the phantom was segmented using optimal threshold. This automatic segmentation technique is insensitive for the signal drift. The average signal intensities were then calculated and should ideally be identical if there was no drift. If we can model the intensity drift we can correct for it during post processing. The unweighted gradient images are typically acquired before the weighted gradient images, but by placing the unweighted gradient directions at regular intervals in between the weighted gradient directions in the gradient table, it is possible to obtain enough information to correct for the drift a no or little extra cost in acquisition time (depending on the number of unweighted gradient directions). With the model for the intensity drift we can perform simulations on the effect on ADC, FA and primary diffusion direction. We ran the simulation 10000 times (each time with a arbitrary tensor orientation) for different values of FA between 0 and 1.0, holding a fixed value of ADC of 1.0×10^{-3} mm^2/s which is close to human white matter tissue.



Results and discussion

The signal intensity dropped 8% from the first to the last unweighted gradient direction. After correction the difference was reduced to less than 0.3%. Without correction the ADC was constantly overestimated by almost 6% and the FA was underestimated by 3-4% in the range typically found in white matter (FA=0.2-0.8). The primary diffusion direction which is used in tractography algorithms such as FACT is on average 1-2 degrees away from the correct direction for FA values typically found in WM. This could potentially lead to erroneous fiber tracts.

References

[1] P. J. Basser and C. Pierpaoli,. *J. Magn. Reson. B* 1996; **111**, 209-219. [2] Mori et al., PCM.. *Ann Neurol* 1999; **45**: 265-269. [3] Reese et al., Proceedings 6th Annual Meeting of ISMRM, Sydney, Australia.