Rigid body motion correction for pediatric spinal cord DTI: improving gray matter-white matter definition

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Purpose

Physiological motion can create significant problems in diffusion tensor imaging (DTI), particularly in imaging of the spinal cord. Spinal cord DTI is complicated by oscillation and pulsation of the cord itself, and by noise introduced by cardiac and respiratory motion. Gating can be used, but results in longer scan times which are poorly tolerated by pediatric subjects in particular. If motion is not corrected for in post processing, results of DTI analysis are impacted, including poor delineation of the cord/CSF interface, and poor gray/white matter differentiation. The purpose of this work was to demonstrate the efficacy of rigid body motion correction techniques in improving cord/CSF conspicuity and gray/white matter definition.

Methods

DTI data was collected for six pediatric subjects on a Siemens Verio 3T MRI scanner using an inner field of view EPI sequence with 2DRF excitations. Imaging parameters were: TE = 110 ms, TR = 7900 ms, Voxel size 0.8 x 0.8 x 6 mm^3, 20 diffusion weighted directions, 3 averages, 6 b0 acquisitions, b = 800 s/mm^2. Prior to motion correction, a mask was applied to the center of the image to eliminate extraneous information beyond the spinal canal which could have unwanted influence on the registration. First, all b0 acquisitions were co-registered by rigid body transformation and averaged to create a mean b0 image using SPM (www.fil.ion.ucl.ac.uk/spm/). After generating the mean b0 image, all diffusion weighted images were registered to the mean b0 image using a rigid body normalized mutual information registration method implemented in the ACID toolbox for SPM (1). ROI analysis was then performed on FA maps generated using MedINRIA software (www-sop.inria.fr/asclepios/software/MedINRIA/) from the corrected images. For each subject, ROIs were drawn on three adjacent axial slices to include lateral and posterior white matter and exclude gray matter as best as possible (Figure 1). FA values for these ROIs were then calculated and examined for both corrected and uncorrected images.

Results

Clear improvements were visible in cord/CSF delineation and in gray/white matter definition in FA maps after motion correction (Figure 2). In some cases, depending on subject motion, improvement was dramatic, even making initially unusable data clear. In all cases, corrected images showed higher FA values for white matter ROIs compared with uncorrected images, ranging from 3-38% increases (Table 1).

Discussion

The rigid body correction algorithm used was effective in improving both cord/CSF interface clarity and gray/white matter contrast. We have previously reported the effectiveness of rigid body motion correction for spinal cord DTI with lower in-plane resolution images (2), and applying these techniques to sub-millimeter in-plane resolution images has resulted in greatly improved contrast which aids in ROI definition. Quantitatively, the increase in white matter FA was consistent but variable which is likely due to the extent to which motion had corrupted the original data set.

Conclusion

The motion correction technique described was effective in post processing of spinal cord DTI data. Post-correction images were clearer with better definition of cord/CSF interface as well as improved gray/white matter definition. The improvements in gray/white matter segregation were also reinforced by the increase in FA values for white matter ROIs in the corrected data.

Subject	Pre FA (+/- SD)			Post FA (+/- SD)			% Increase
1	0.60	±	0.08	0.68	±	0.07	13%
2	0.72	±	0.10	0.74	±	0.07	3%
3	0.64	±	013	0.70	±	0.07	9%
4	0.50	±	0.10	0.65	±	0.07	30%
5	0.47	±	0.16	0.65	±	0.09	38%
6	0.64	±	0.14	0.75	±	0.05	17%

Table 1 – Pre and post correction FA values for white matter ROIs. ROIs were defined on three consecutive slices for each subject.

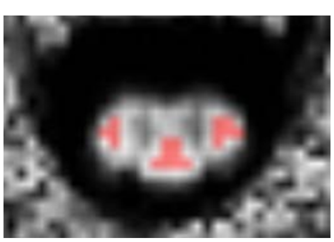

Figure 1 – Shows a representative axial spinal cord slice showing pattern for white matter ROI definition

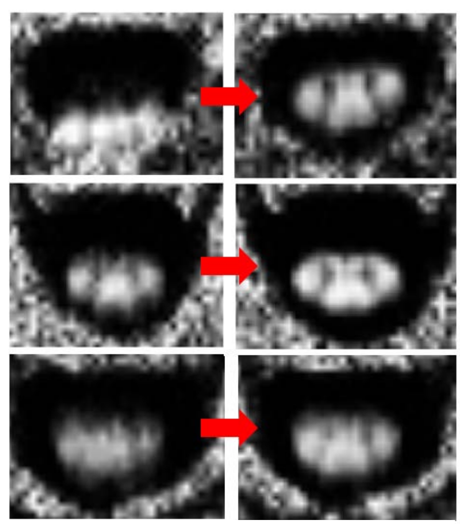

Figure 2 – Pre (left) and post (right) correction FA maps for axial slices from three subjects showing improved gray/white matter definition and cord/CSF interface conspicuity.

References: (1) Mohammadi S, Moller HE, Kugel H, et al. Correcting eddy current and motion effects by affine whole-brain registrations: evaluation of three-dimensional distortions and comparison with slicewise correction. Magn Reson Med 2010:64: 1047-1056; (2) Middleton, DM, Mohamed FB, Barakat N, et al. An investigation of motion correction algorithms for pediatric spinal cord DTI in healthy subjects and patients with spinal cord injury. Magn Reson Imag 2014 (in press).