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Potential impact of Prospective vs Retrospective Motion Correction in a Longitudinal Study

Introduction

Diffusion tensor imaging (DTI) is a noninvasive imaging technique for quantifying microstructural white matter (WM) changes associated with normal development and disease. Head motion during acquisition of diffusion weighted images (DWIs) results in misalignment and signal dropout. While algorithmic corrections are often applied retrospectively, these cannot compensate for dropout, diffusion gradient errors, and induce a bias in reconstructed tensors [1,2]. Recently, several proposals have been made for prospective motion correction [1,3,4]. As techniques improve, longitudinal studies must balance methodological bias inherent in existing techniques against improvements gained by implementing better approaches into data collection and analysis.

In this study, we compare two motion correction methods within an ongoing longitudinal study of children. We examine differences in mean fractional anisotropy (FA) values and tractographic corticospinal WM reconstruction from DWIs acquired with each method. Method 1 uses "standard" steps, accounting for motion with retrospective correction techniques (image registration with 12 DOF affine transformation). Method 2 employs prospective motion correction (using a fast volumetric navigator acquired after each DWI [1]).

We examine whether differences in these methods significantly bias mean FA maps and tractographic results in order to assess the inclusion of both techniques within an ongoing longitudinal study.

Methods

Four healthy children (3 female, age range: 7.1-7.3 yrs) from a longitudinal study underwent standard [5] DTI (1), prospectively corrected DTI (2), and a T1-weighted scan on a 3T Siemens Allegra in Cape Town, South Africa. (1) and (2) each comprised two acquisitions with opposite phase encoding directions; DTI used a twice-refocused SE-EPI sequence.

DTI (1): TR/TE 9500/86 ms, 70 slices, matrix size = 112 x 112, in-plane FOV = 224 x 224 mm^2, slice thickness = 2mm, 30 diffusion directions, b = 1000 s/mm^2, four b_0 scans.

DTI (2): same as (1), except TR = 100026 ms (due to included navigator) and five reacquisitions enabled in case of motion.

Retrospective motion correction using FLIRT in FSL [6] (12 DOF) was applied to DWIs from (1). Susceptibility distortion and outlier rejection were applied to correct for EPI distortion [7]. T1 images were co-registered to an anatomical template image for children aged 7 - 11 years [8]. FA maps were warped to standard space. Voxelwise group comparisons were performed in FSL for (1) vs (2); regions where (1) and (2) differ (clusters ≥ 230 mm^3) at $p < 0.05$ are reported. Tractography analysis was done using FATCAT in AFNI [9].

Results

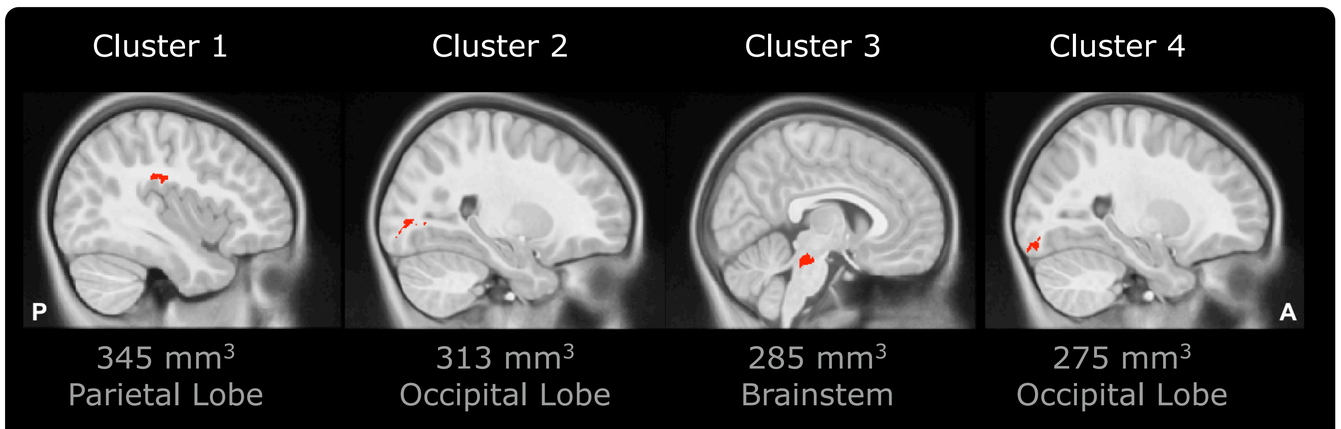

Figure 1. A voxelwise comparison of FA maps found significant differences ($p < 0.05$) in four clusters, each cluster has higher mean FA in method 2 (prospective motion correction). A = Anterior, P = Posterior.

	Retrospective Motion Correction (1)				Prospective Motion Correction (2)			
Subject	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 1	Cluster 2	Cluster 3	Cluster 4
1	0.48	0.24	0.25	0.18	0.57	0.36	0.30	0.25
2	0.51	0.27	0.26	0.21	0.56	0.33	0.30	0.25
3	0.51	0.27	0.26	0.21	0.55	0.32	0.31	0.28
4	0.52	0.25	0.26	0.19	0.57	0.33	0.34	0.28
Mean FA	0.50	0.26	0.26	0.20	0.56	0.34	0.31	0.27

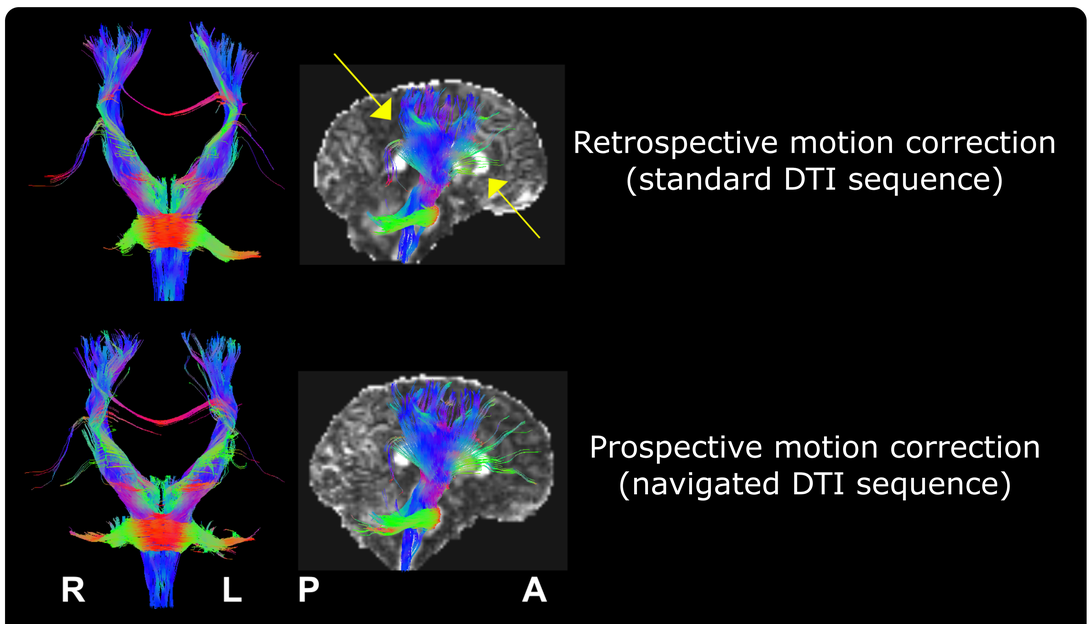

Figure 2. Tractography results for one subject. Yellow arrows highlight tractography differences between two methods. Tractographic comparison of the corticospinal tracts revealed differences in the final reconstructions of the two methods. Prospective motion correction produced more coherent frontal fiber bundles and more generally symmetric tracts.
R = Right, L = Left, A = Anterior, P = Posterior)

Conclusion

In Figure 1, clusters 1 - 4 demonstrate tensor reconstruction differences, which may be attributed to the resultant interpolation from retrospective DWI alignment. In method (1), the mean FA value for all clusters is significantly lower than in method (2), suggesting GM-WM partial volume effects. These results imply method (2) may be more sensitive to identifying WM at a boundary. The increased symmetry and fiber bundle coverage observed in the tractography results of method (2) suggest this method may reduce overall noise included in tensor fits, leading to less error accumulation during tract propagation.

We compared two methods of motion correction (retrospective vs prospective) using two DTI metrics. The results suggest that different motion correction techniques applied to DWIs may introduce potential methodological bias within a longitudinal study.

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