IQ Correlates with Diffusion Tensor Imaging Parameters in Normal Children

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Diffusion Tensor Imaging (DTI) was performed on 65 normal children, ages 5-18. Significant correlations of both fractional anisotropy (FA) and the trace of the apparent diffusion coefficient (TADC) with IQ were found bilaterally in the anterior portion of the inferior longitudinal fasciculi near the temporo-parietal junction. We suggest that these areas may play a prominent role in executive function and cognition in the developing brain.

Introduction

A previous diffusion tensor imaging (DTI) study on normal children [1] found significant correlations of both fractional anisotropy (FA) and trace of the apparent diffusion coefficient (TADC) with age. Increasing FA with age was found primarily in the corticospinal tract, while decreasing TADC was found throughout the white matter. We now aimed to assess a possible correlation of FA and TADC with intelligence in a normal pediatric population.

The significance of white matter for cognitive functions has been shown in such diverse groups of patients like children after therapeutic brain radiation [2] and healthy 80-year-olds [3]. While this exemplifies the importance of global white matter volume or the amount of white matter lesions, as yet no inferences can be made about differences in white matter microstructure of normal brains that correlate with cognitive function. We investigated this correlation by examining white matter diffusion properties in normal children.

Materials and Methods

A 24-slice diffusion-weighted echo-planar imaging sequence was performed on 65 normal children (25M, 40F, mean age = 10.5, SD = 3.3 Yrs.) Imaging parameters were: TR = 6070 ms, TE = 87 ms, Δ = 40 ms, δ = 18 ms, diffusion gradient strength = 30 mT/m, resulting in a b value of 710 s/mm^2. Three scans were acquired with no diffusion weighting, and 25 diffusion-weighted scans were acquired with different diffusion gradient directions determined using an electrostatic repulsive model [4]. Geometric distortion due to gradient eddy currents was minimized using an automated gradient pre-emphasis adjustment routine [5], and any residual distortion was corrected for using a FLAIR-EPI scan with no diffusion weighting as a template. Geometric distortion due to B_0 field inhomogeneity was corrected for using a multi-echo reference scan [6]. In each subject, only the pixels determined to be in white matter, using the segmentation procedure available in SPM99 (Wellcome Department of Cognitive Neurology, London, UK) on an anatomical T1-weighted dataset, were retained for further analysis, to avoid potential partial volume effects. Using routines written in IDL (Research Systems Inc., Boulder, CO), the components of the diffusion tensor were computed and transformed into stereotaxic coordinates. Across all subjects, the FA and TADC values were correlated with results from the Wechsler Intelligence Scale for Children (Third Edition: Full-Scale IQ) on a pixel-by-pixel basis, with gender and global white matter volume being used as covariates, to account for effects due to gross morphological differences. Regions with statistically significant correlations were determined using the criterion of at least 15 contiguous pixels with a p-value of 0.05 or less. A Monte Carlo simulation showed that the chosen p-value and cluster size resulted in one false positive voxel on average.

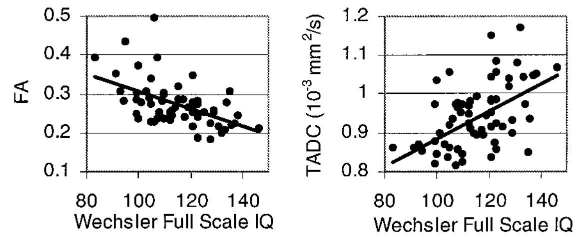

Figure 1. Average FA (left) and average TADC (right) plotted as a function of IQ, for all significantly correlated pixels in the inferior longitudinal fasciculi.

Results and Discussion

Regions of significantly decreasing FA and significantly increasing TADC as a function of age were found near the temporo-parietal junction in the anterior portions of the inferior longitudinal fasciculi (FLI) bilaterally. Graphs of the average FA values and average TADC values for all significantly correlated pixels in the FLI are shown in Figure 1. These correlations are highly significant ($p<1e-5$ for both FA and TADC).

Our findings indicate a structural difference in specific white matter areas between children with a higher and children with a lower IQ. Children with a higher IQ have lower FA and higher TADC values in specific white matter tracts. This could be caused by changes in fiber diameter or in the temporal evolution of organization (e.g. by the elimination of unnecessary / inefficient fibers). However, which mechanism is ultimately responsible for our findings is at present unclear.

Conclusion

DTI was performed on a normal pediatric population and the results show significant changes of both FA and TADC in specific brain areas. Individual cognitive functions seem to be reflected in differences of white matter architecture not explained by gender or global volume differences. Further research on these differences and the cortical areas they subserve may help in bringing about a deeper understanding on the physiology of cognitive processes.

References

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