Assessment of structural maturation of the optic radiation in children with probalistic tractography

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Introduction

The myelination of the visual pathway white matter has been shown to reach adult maturity before 3 years old with myelin staining on histological sections of dissected brains [1]. Diffusion tensor imaging and tractography provide an opportunity to assess in vivo, the structural maturation of the optic radiations (OR) in children. The objective of this study was to determine diffusion tensor metrics in the OR segmented using tractography in a cohort of children aged 7 to 18 years and to determine the relation between these metrics and age, hemisphere and gender.

Methods

Subjects: 15 children participated in the study without any known medical condition (healthy controls) for which informed consent was obtained. The subjects were composed of 8 boys and 7 girls aged 11.8 ± 3.7 years (range 7 to 18).

DTI data acquisition: The DTI data were acquired on a 1.5 T Siemens Avanto system with a double refocused spin echo EPI sequence, 45 contiguous 2.5 mm slices (averaged for two acquisitions with TE = 89 m), 20 non-collinear directions, b values of 0 and 1000 s.mm^{-2}. This protocol was repeated 3 times and lasted less than 15 minutes. The reconstructed voxel size was 2.5 mm isotropic.

DTI processing: Correction for eddy currents and small movements was carried out by registering all volumes to the 1st b=0 volume with a 12-parameter affine transformation (with FSL [1]). DT fitting was implemented with linear least-squares (with Camino [2]).

Tractography: Tractography was carried out using 10000 iterations of the DT PICo algorithm [3] without any angular threshold to account for the high curvature of ML. A 16-voxel seed region was placed in each hemisphere anterolaterally to the lateral geniculate nucleus in a coronal plane intersecting ML. Tractography was constrained by placing a waypoint ROI to include the stratum sagittale and exclusion ROIs medially (to prevent tracking of the anterior commissure and forceps major), laterally (acoustic radiation) and anteriorly (inferior occipito-frontal and uncinate fasciculi). As the exclusion ROIs trimmed most of the artifactual tracts, the PICo threshold was set to 0.01%.

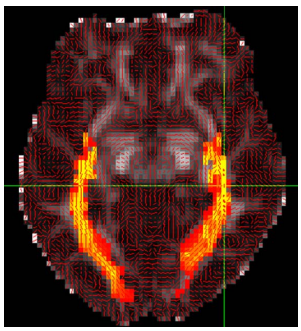

Figure 1: probability map from the PICo algorithm.

Quantitative and statistical analysis: The mean FA and axial and radial diffusivity were computed in the segmented OR of each hemisphere. To account for any difference between the left and right hemisphere and any gender or age effect, the data were subjected to a multiple regression analysis.

Results and Discussion

Tractography: The OR could be reconstructed successfully with the PICo tractography method with the Meyer's loop being visible in all subjects (cf. probability map in Figure 1 in which the probability range linearly from 0 in red to 1 in yellow). The planar exclusion masks introduced to exclude many neighbouring tracts at that particular location may have prevented the reconstruction of part of its tip anteriorly (up to 1cm), which was considered negligible in the quantitative analysis based on the full length of the tract (greater than 90 cm).

Quantitative and statistical analysis: There was no evidence for a FA difference between sides (t test p-value > 0.96), while the side effect was significant for both the axial and radial diffusivity ($p \leq 0.01$). The data were therefore averaged across hemisphere for the mean FA and analysed separately for each hemisphere for the axial and radial diffusivity. A multiple regression analysis did not demonstrate any gender effect for any of the DT indices (p values > 0.3) nor any age effect for the axial diffusivity. In contrast, a significant age dependence was found for the radial diffusivity ($p < 0.04$) and FA ($p < 0.001$) associated with an age coefficient of 0.0046/year with 95% confidence interval [0.0022,0.0071]/year (Figure 2). Similarly, age coefficients and 95% confidence interval for the radial diffusivity were calculated to be -0:006 [-0:012; 0:000] and -0:005[-0:009; 0:000]x10^{-3}mm^2.s^{-1}/year for the left and right OR respectively (Figure 3). To the knowledge of the authors, only [5] mentioned an age effect in FA limited to parts of the ventral pathway, based on SPM analysis, and [6] based on tractography with FA in a smaller cohort than our study. This age-related effect could be related to the continuous evolution of object representation and complex stimuli integration (e.g. social interaction) suggested to develop during late childhood and adolescence.

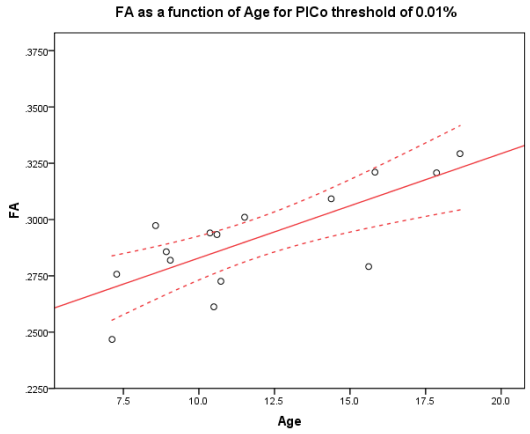

Figure 2: mean FA within the OR with respect to age.

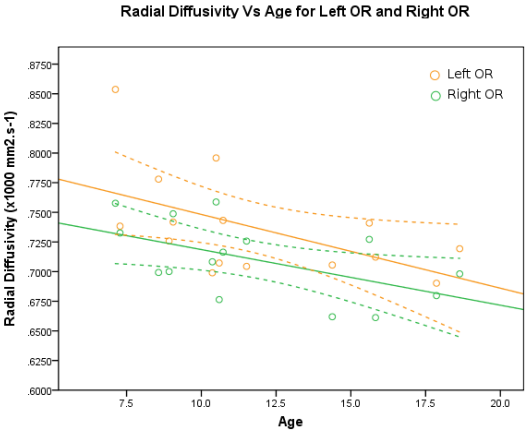

Figure 3: mean radial diffusivity within the left OR (orange) and right OR (green) with respect to age.

Conclusions

Despite being well above the age when myelin finishes maturing, tractography based analysis of the OR indicated a significant age effect to be present for both FA and radial diffusivity. These findings suggest that structural changes are ongoing in the optic radiations in children long after myelination is complete. The outcome of this study has important implications for future studies of visual dysfunction in children based on DT indices and tractography such as those, for example, with amblyopia or optic nerve hypoplasia, indicating that age related effects in this age range should be taken into account.

References

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