Understanding the Effects of Prematurity on the Visual System using Diffusion MRI

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Background: Children born very preterm are at high risk for adverse sensory and neurodevelopmental outcomes including visual impairments later on in life. Although abnormal visual function has been mostly attributed to ocular diseases or injury to the visual cortex, the connectivity and development of white matter microstructure within the optic radiation of the visual system may also play a role in abnormalities of visual development in very preterm children. The aims if this study were to investigate 1) the microstructural organization of the visual pathway and the course of white matter tracts using diffusion MRI, 2) the effects of prematurity on the development of the optic radiation, 3) and the association between microstructural integrity of the optic radiation and abnormal visual development.

Methods: 142 very preterm children (<30 weeks' gestational age and/or birth weight <1250g) and 32 full-term children were scanned at 7 years of age with a Siemens Trio 3T scanner using a 32 channel head coil. b1200 diffusion-weighted images (TR, 1200 ms; TE, 96 ms; matrix, 144 x 144; FOV, 250 x 250 mm; isotropic voxels, 1.7 mm^3; 25 gradient directions with b values ranging 0 to 1200 s/mm^2) and b3000 diffusion-weighted images (TR, 7400 ms; TE, 106 ms; matrix, 104 x 104; FOV, 240 x 240 mm; isotropic voxels, 2.3 mm^3; 45 gradient directions with b value= 3000 s/mm^2, and 5 b value= 0 s/mm^2 volumes) were acquired. Optic radiations were reconstructed using probabilistic fibre tractography based on constrained spherical deconvolution. Tract volume and diffusion parameters within 3 regions of the optic radiation (average of left and right) were compared between groups and correlated with visual outcomes. Visual acuity was assessed using the standard Snellen eye chart and visual field defects were assessed by a clinician using the confrontation technique.

Results: Both the anterior and middle regions of the optic radiation had significantly larger radial and mean diffusivity (Table 1). There were no significant differences between preterm and full-term children for tract volume fractional anisotropy, or axial diffusivity measures, or for tract measures within the posterior segment. Visual field defects were associated with a higher radial diffusivity (p=0.0001) in the anterior segment and lower fractional anisotropy (p=0.0008) in the middle segment of the optic radiation. A smaller tract volume in the posterior segment was associated with poorer visual acuity in both the left (p=0.02) and right (p=0.02) eyes.

Table 2. Comparison of optic radiation measures between pre-term and term subjects

Segment	Diffusion and volume values	Mean (SD)		Mean Difference (95% CI)	p-value
		Pre-term	Full Term		
Anterior	$\lambda^{\perp}$	0.59 (0.06)	0.57 (0.03)	-0.02 (-0.03, -0.005)	**0.008**
	MD	0.86 (0.06)	0.84 (0.03)	-0.02 (-0.03, -0.006)	**0.005**
Middle	$\lambda^{\perp}$	0.63 (0.09)	0.59 (0.04)	-0.04 (-0.06, -0.02)	**0.0003**
	MD	0.88 (0.08)	0.84 (0.04)	-0.04 (-0.06, -0.01)	**0.0009**

SD= standard deviation, CI= confidence interval, MD = mean diffusivity($x10^{-3}$ mm^2/s), $\lambda^{\perp}$ = radial diffusivity ($x10^{-3}$ mm^2/s).

Conclusions: The connectivity and organization of the optic radiation is less well developed in very preterm children than term controls at 7 years of age, which may reflect impaired myelination. The more anterior and middle regions appeared most vulnerable. Altered microstructural organization of the optic radiation has a negative impact on visual function at 7 years.