FA and directional diffusivities of normal white matter maturation from late childhood to young adulthood

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Aim: We evaluate fractional anisotropy (FA), radial ($\lambda_\perp$) and parallel ($\lambda_{//}$) diffusivities of the brain white matter at late childhood, early adolescence and young adulthood, representing a period of maturation of cognitive processes, language and reading abilities.

Materials and methods: We randomly recruited normal healthy volunteers of three age-groups (Group 1, 2, 3) for cross-sectional DTI studies. Raven's Standard Progressive Matrices was used as an index of nonverbal intelligence for Group 1 and 2. Subject demographics are summarized in Table 1. Using SPM2, T2 weighted image was first coregistered to non-diffusion weighted(b0) image from DTI and then normalized to T2 template. The resultant normalization parameter was applied to FA image to bring it into standard space. A total of 7 regions-of-interest were drawn manually or with semi-automated method from the normalized maps to quantify FA, $\lambda_\perp$ and $\lambda_{//}$ for each age-group. These were the frontal (FWM) and parietal (PWM) white matter, the anterior limb of the internal capsule (ALIC) and posterior limb of the internal capsule (PLIC), the genu (CC genu), body (CC body) and splenium (CC splenium) of the corpus callosum. Analysis of Variance (ANOVA) was used to test for statistical significance in DTI indices among the 3 groups.

Subject demographics		Group 1	Group 2	Group 3
No. of subjects		*24*	*27*	*24*
Age /years	Range	6.8 - 7.9	9.4 - 11.5	18.6 - 26.1
	Mean (SD)	7.4 (0.3)	10.3 (0.5)	22.8 (2.3)
Gender	Male	13	16	11
	Female	11	11	13
IQ score(Raven) Mean (SD)		35.5 (7.0)	44.1 (3.4)	N/A

Table 1 showing subject demographics of Groups 1, 2, 3

Imager	3T Siemens
B factor and DWI	1000 $mm^{-2}s$, 6 directions + 1 b0
Repetition	4
TR/TE	6000/84ms
FOV	192 × 192 cm
Acquisition matrix	64 × 64
Slice thickness	3mm without gap

Table 2 showing protocol of diffusion tensor imaging

Results: There was significant increase in FA in the projection fibres (FWM, PWM, ALIC, PLIC) and trend of increase in FA in the splenium of the CC from late childhood through adolescence to young adulthood. There was corresponding decrease in both $\lambda_{//}$ and $\lambda_\perp$ with greater decrease in $\lambda_\perp$ leading to increase in FA (Table 3).

Region	Grp 1 (n=24)	Grp 2 (n=27)	Grp 3 (n=24)	p
FA Mean(SD)				
CC genu	0.598 (0.065)	0.597 (0.059)	0.573 (0.092)	0.390
CC body	0.609 (0.062)	0.571 (0.078)	0.579 (0.075)	0.163
CC splenium	0.717 (0.111)	0.761 (0.077)	0.762 (0.064)	0.122
ALIC	0.459 (0.052)	0.490 (0.043)	0.518 (0.054)	<0.001
PLIC	0.594 (0.031)	0.605 (0.024)	0.633 (0.035)	<0.001
FWM	0.388 (0.012)	0.394 (0.014)	0.405 (0.015)	<0.001
PWM	0.359 (0.016)	0.370 (0.014)	0.382 (0.017)	<0.001
$\lambda_{//}$ Mean (SD) $\times 10^{-3}$ mm^2/s				
CC genu	2.01 (0.13)	1.97 (0.21)	1.91 (0.14)	0.100
CC body	1.88 (0.17)	1.82 (0.12)	1.84 (0.14)	0.399
CC splenium	1.98 (0.15)	1.97 (0.10)	1.92 (013)	0.143
ALIC	1.32 (0.07)	1.34 (0.06)	1.29 (0.09)	0.075
PLIC	1.44 (0.04)	1.41 (0.04)	1.38 (0.05)	<0.001
FWM	1.23 (0.02)	1.19 (0.02)	1.12 (0.02)	<0.001
PWM	1.19 (0.02)	1.16 (0.02)	1.14 (0.03)	<0.001
$\lambda_\perp$ Mean (SD) $\times 10^{-3}$ mm^2/s				
CC genu	0.728 (0.139)	0.707 (0.151)	0.730 (0.179)	0.837
CC body	0.668 (0.161)	0.708 (0.175)	0.710 (0.172)	0.627
CC splenium	0.508 (0.169)	0.436 (0.135)	0.413 (0.107)	0.054
ALIC	0.591 (0.038)	0.561 (0.034)	0.509 (0.036)	<0.001
PLIC	0.483 (0.030)	0.465 (0.025)	0.429 (0.032)	<0.001
FWM	0.666 (0.022)	0.635 (0.020)	0.596 (0.018)	<0.001
PWM	0.677 (0.026)	0.648 (0.019)	0.634 (0.023)	<0.001

Table 3 showing FA, $\lambda_{//}$ and $\lambda_\perp$ of 7 ROIs among 3 age groups

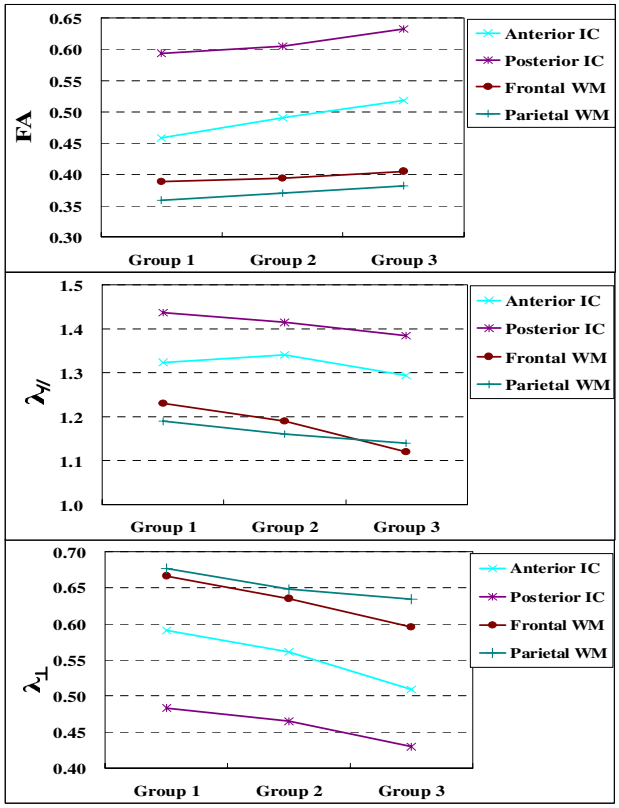

Fig. 1 showing trend plots of FA, $\lambda_{//}$ and $\lambda_\perp$ among 3 age groups

Conclusion: Only few studies have described FA and directional diffusivity changes in late childhood through adolescence and early adulthood [1,2]. Our findings are in keeping with continued maturation of projection fibres into early adulthood with increase in FA and decrease in both $\lambda_{//}$ and $\lambda_\perp$. Although the exact biophysical mechanisms underlying the changes of FA and directional diffusivities remain to be elucidated, these findings may arise from a combination of increased myelination, axonal packing, axonal growth and protein content (neurofilaments and microtubules) [3].

References:

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