Diffusion tensor imaging of healthy neonates and children up to adolescence

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Introduction: Diffusion tensor imaging (DTI) provides a new diagnostic method for estimating myelination *in vivo* [1]. We studied the development of the human brain using the apparent diffusion coefficient (ADC) and the fractional anisotropy (FA) in children and adolescents. Knowledge of such normative data may prove highly valuable for comparative studies in sick children.

Patients and Methods: 133 subjects (68 females, 65 males; age range: 20 days to 25 years) without neuroradiological or pathologic findings were examined. MRI was performed on a 1.5 T MR scanner using a TRSE-EPI-DTI sequence (6 directions; b=0/1000sec/mm²; FOV=240mm; matrix=128; in-plane resolution 1.8 × 1.8 mm²; 19 slices, 5mm thick). ADC and FA were calculated for each voxel and 20 bilateral ROIs were manually defined on the b_0-images, ADC and FA maps (examples shown in Fig.1). For statistical analysis Spearman correlation coefficient was calculated for each ROI.

Results: A significant decrease of ADC with age was observed in 32 of 40 regions, most prominently in the frontal regions. FA increased significantly with age in 35 of 40 regions. Largest changes in both parameters were observed during the first months of life [2]. Logarithmic and exponential functions best fit the ADC and FA data, respectively:

$$ADC = \beta_0 + \beta_1 \cdot ln(x)$$

$$FA = \beta_0 + e^{\beta_1 \cdot x}$$

(where x is the age of the patient in years)

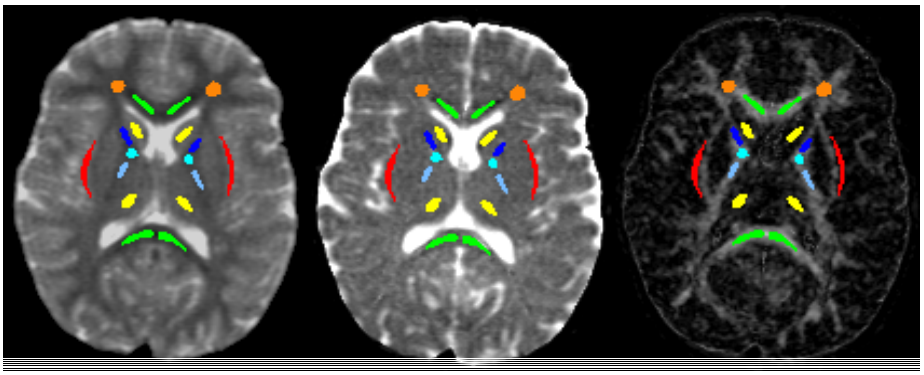

Fig. 1: b_0 ADC FA

Resulting graphs for the right frontal white matter are shown below (Fig. 2a/b).

While β_1 describes the strength of change in ADC and FA as the brain matures (the larger β_1, the faster the change), Spearman correlation coefficient (r) and the r^2 value describe the connection between ADC / FA and age (Tab.1).

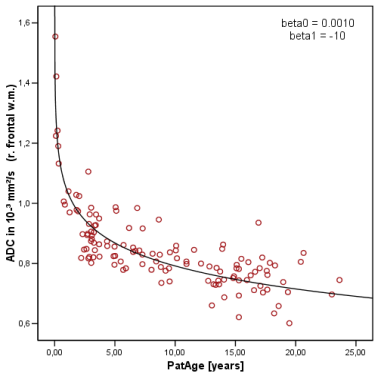

Fig. 2a ADC as a function of age for right frontal white matter.

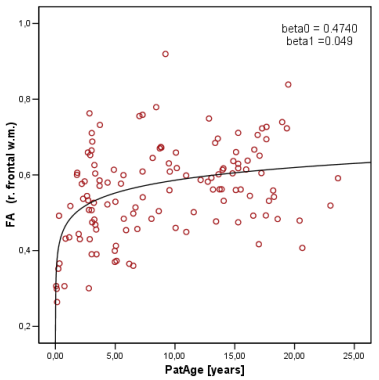

Fig. 2b FA as a function of age for right frontal white matter.

Discussion: ADC and FA can be used to describe the development of the human brain. The change in ADC and FA may be an indicator of the stage of myelination, axonal structure and water content. Both quantities as well as their changes are also dependent on the location in the brain. This suggests that different brain regions mature at different periods of life and that the patients age has to be taken into consideration if diffusion is studied in patients.

Region of interest	ADC				FA			
	beta0 [mm²/s]	beta1[mm²/s]	Spearman	r²	beta0	beta1	Spearman	r²
l. c.c. (genu)	0.0011	-8	-0.441	0.19	0.8851	0.060	0.443	0.20
r. c.c. (genu)	0.0011	-7	-0.360	0.13	0.8476	0.076	0.561	0.31
l. c.c. (splenium)	0.0011	-4	-0.385	0.15	0.9439	0.056	0.392	0.15
r. c.c. (splenium)	0.0011	-6	-0.371	0.14	0.8999	0.055	0.474	0.22
l. i.c. (ant. limb)	0.0009	-5	-0.491	0.24	0.6927	0.073	0.595	0.35
r. i.c. (ant. limb)	0.0009	-5	-0.487	0.24	0.7457	0.052	0.559	0.31
l. i.c. (genu)	0.0010	-3	-0.218	0.05	0.7665	0.062	0.499	0.25
r. i.c. (genu)	0.0010	-3	-0.334	0.11	0.7769	0.055	0.439	0.19
l. i.c. (post. limb)	0.0009	-5	-0.631	0.40	0.7659	0.046	0.560	0.31
r. i.c. (post. limb)	0.0009	-5	-0.665	0.44	0.7753	0.047	0.575	0.33
l. insular cortex	0.0010	-5	-0.634	0.40	0.2846	0.020	0.247	0.06
r. insular cortex	0.0010	-5	-0.697	0.49	0.2922	0.009	-0.005	0.00
l. thalamus	0.0009	-5	-0.717	0.51	0.3387	0.016	0.145	0.02
r. thalamus	0.0009	-4	-0.627	0.39	0.3881	0.032	0.333	0.11
l. c.ncl. (head)	0.0009	-7	-0.761	0.58	0.2874	0.024	0.234	0.05
r. c.ncl. (head)	0.0009	-6	-0.745	0.56	0.3348	0.011	0.040	0.00
l. frontal w.m.	0.0010	-10	-0.736	0.54	0.4846	0.048	0.367	0.13
r. frontal w.m.	0.0010	-10	-0.788	0.62	0.4740	0.049	0.367	0.13
shortcuts: Spearman = Spearman correlation coefficient, l.= left, r.= right, c.c.= corpus callosum, i.c.= internal capsule,								
c.ncl.= caudate nucleus, w.m.= white matter, n.s.= not significant								

Tab. 1 Summary of ROI evaluation and fit parameters.

References: [1] Moseley M. Diffusion tensor imaging and aging - a review. NMR Biomed. 2002 Nov-Dec;15(7-8):553-60. **[2]** Forbes KP, Pipe JG, Bird CR. Changes in brain water diffusion during the 1st year of life. Radiology. 2002 Feb;222(2):405-9.