Serial Measurements of Water Diffusion Parameters in Grey and White Matter after Human Ischaemic Stroke

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Introduction

Results from studies on the temporal evolution of water diffusion parameters after human ischaemic stroke show inconsistencies, specifically relating to the time at which ADC pseudo-normalisation occurs. These could be caused by heterogeneity of the diffusion parameters within the lesion, potentially arising from different water diffusion properties of grey and white matter. Several previous studies have evaluated the evolution of grey and white matter diffusion parameters[1-3], however some had small number of patients, others did not measure diffusion anisotropy and not all were specifically designed to analyse differences between the two tissue types. Our purpose was to investigate possible differences in the values and temporal evolution of the mean diffusivity ($\langle D \rangle$) and fractional anisotropy (FA) in grey and white matter after human ischaemic stroke by tracking the same patients over time.

Methods

Thirty-two patients underwent serial diffusion tensor imaging (DTI) at different time points after stroke (<24 hours, 4-7, 10-14, 30 and 90 days). None of the patients received neuroprotective or thrombolytic drugs and all lesions affected both grey and white matter. Outlines were traced on all slices around the hyperintense lesion on the first time-point diffusion-weighted images. Using T_2-weighted images, multiple small circular regions-of-interest (ROI) were placed in grey and white matter within the lesion and in comparable contralateral tissue. ROI were copied onto the co-registered follow-up scans and values of $\langle D \rangle${grey}, $\langle D \rangle${white}, FA{grey}, and FA{white} were measured in these ROI at the five time points. To allow comparisons among individuals and between initial and subsequent scans, the ratio of $\langle D \rangle$ and FA values in the lesion and normal contralateral brain, $\langle D \rangle_R$ and FA_R, were calculated. To ensure that within patient effects, rather than inter-patient variability were tested, differences between $\langle D \rangle_R$ and FA_R values of grey and white matter were assessed using a two-tailed Student's paired t-test with $p < 0.05$ being considered significant.

Results

Figure 1 (a) and (b) show different patterns of evolution in $\langle D \rangle$ and FA after stroke for grey and white matter. After the initial decline, the rate of increase of $\langle D \rangle${grey} is faster than $\langle D \rangle${white} between 4-7 and 10-14 days. FA{white} decreases more rapidly than FA{grey} during the first five days, decreasing gradually thereafter for both tissue types. However, FA{white} is higher than FA{grey} at three months indicating that some tissue structure remains. Relative values show that $\langle D \rangle_R${white} is significantly lower than $\langle D \rangle_R${grey} at <24 hours and 10-14 days (p<0.05) and $\langle D \rangle_R${grey} pseudo-normalises earlier (*cf.* Table 1). FA_R{white} is significantly more reduced than FA_R{grey} at all time points (p<0.001).

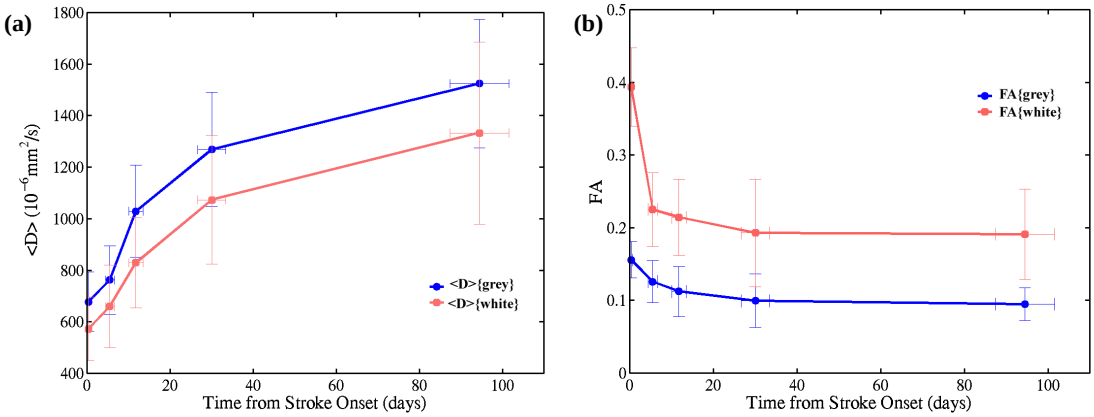

Figure 1. Temporal evolution of the absolute mean values of the **(a)** mean diffusivity ($\langle D \rangle$) and **(b)** fractional anisotropy (FA) of lesion grey and white matter after ischaemic stroke

Table 1. Relative values of mean diffusivity ($\langle D \rangle_R$) and fractional anisotropy (FA_R) for grey and white matter at each time point. Bold type indicates a significant difference ($p < 0.05$) between grey and white matter values at that time point. Values are shown as Mean ± SD.

Time (days)	$\langle D \rangle_R$			FA_R		
	Grey	White	p	Grey	White	p
0.3 ± 0.3	**0.74 ± 0.13**	**0.69 ± 0.14**	**0.02**	**1.00 ± 0.19**	**0.86 ± 0.13**	**< 0.001**
5.5 ± 1.1	0.79 ± 0.13	0.79 ± 0.18	0.99	**0.90 ± 0.17**	**0.54 ± 0.14**	**< 0.001**
11.7 ± 1.7	**1.05 ± 0.19**	**0.97 ± 0.19**	**0.03**	**0.80 ± 0.22**	**0.52 ± 0.15**	**< 0.001**
30.0 ± 3.4	1.32 ± 0.23	1.28 ± 0.29	0.47	**0.73 ± 0.26**	**0.46 ± 0.17**	**< 0.001**
94.5 ± 7.1	1.60 ± 0.25	1.60 ± 0.42	0.97	**0.69 ± 0.20**	**0.46 ± 0.17**	**< 0.001**

Conclusions

This is the largest longitudinal study to date investigating the temporal evolution of water diffusion parameters in grey and white matter after stroke. By following individual patients over time who had lesion affecting both grey and white matter, evidence has been found that the temporal evolution of $\langle D \rangle$ and FA is different for grey and white matter. Studies quantifying changes in whole lesion water diffusion parameters after stroke should take into account the extent of grey and white matter within the infarct.

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