Comparing Mean and Directional Diffusivity in Human Ischemic Stroke

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Introduction

Diffusion weighted MRI and the derived apparent diffusion coefficient (ADC) has proven to be extremely sensitive to detect early ischemic stroke in patients. However, clinical outcomes are variable and do not always correlate the ADC abnormalities. Diffusion tensor imaging (DTI) has shown promise to not only detect lesions in central nervous system disorders in human and animal models, but also allows for MRI specific analysis of the underlying brain architecture. Recent studies have demonstrated an analytical approach to interpret the DTI derived parameters, using axial diffusivity ($\lambda_{\parallel}$) and radial diffusivity ($\lambda_{\perp}$), for assessing the extent of axonal or myelin injury in the CNS white matter of mice. We here to apply this approach to ischemic stroke patients and compare with the widely used ADC and the anisotropy index, scaled relative anisotropy (sRA).

Materials and Methods

Patients

In all, 9 patients (5M, 4F; mean age = 53 ± 19 years) presenting with the symptom of ischemic stroke (7 acute/subacute cases, onset 2-14 days; 2 chronic cases, onset 6-7 years) were retrospectively enrolled in the magnetic resonance imaging study. MRI protocols were approved by the local IRB.

Image Acquisition

Imaging was performed on the 3 Tesla TIM Trio or 1.5 Tesla TIM Symphony with quantum gradient using 12 channel head coils. A single shot spin-echo echo-planar imaging (EPI) was used for DTI acquisition at the TIM Trio with the following parameters: 60 slices without a gap, FOV =190 mm, phase FOV = 100 %, thickness = 2 mm, base resolution = 96, phase resolution = 100 (that makes voxel size = 2 × 2 × 2 mm), phase partial Fourier = 6/8, TR = 9900 msec, TE = 102 msec, average = 1, *b*-value = 1400 sec/mm^2, directions = 25, bandwidth = 1080 Hz, EPI factor = 96, echo spacing = 1 msec. A similar protocol was set up for the TIM Symphony with 2.5 × 2.5 × 2.5 mm isotropic voxels.

Postprocessing and Data analysis

Multiple parameters were derived from the diffusion tensor measurements including ADC, scaled RA (sRA, defined as the standard deviation of the three eigenvalues normalized by the ADC divided by 1.4), axial diffusivity ($\lambda_{\parallel}= \lambda_1$), and radial diffusivity ($\lambda_{\perp}=\lambda_2+\lambda_3/2$) off-line. (Fig.1.) Analyze 7.0 (Biomedical Imaging Resource, Mayo Clinic) was used to draw regions of interest (ROIs) on the center of white matter and the contralateral normal-appearing tissues. The ratios between the lesion and control sides were measured as ADC ratio (ADCr), sRA ratio (sRAr), axial diffusivity ratio (ADr), and radial diffusivity ratio (RDr).

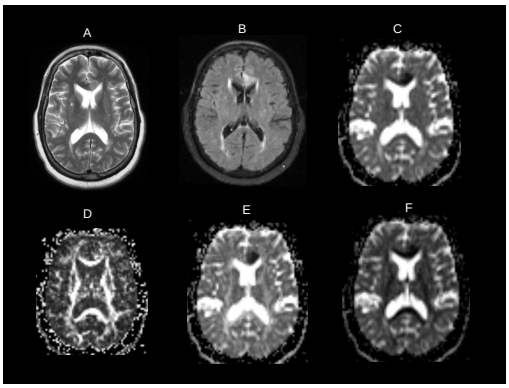

Fig 1. *A: T2WI; B: FLAIR; C: ADC map; D: sRA map; E: Axial diffusivity map; F: radial diffusivity map.* The above graph shows a case suffered from a left anterior cerebral artery (ACA) infarction.

	Acute/subacute		Chronic	
	values	*p*	values	*p*
ADCr	0.63 ± 0.20	<0.01	3.07 ± 0.49	<0.01
sRAr	0.72 ± 0.35	NS	0.31 ± 0.23	<0.01
ADr	0.53 ± 0.20	<0.01	2.22 ± 0.38	<0.01
RDr	0.84 ± 0.36	NS	4.06 ± 1.09	<0.01

Table 1 presents parameter ratios in ischemic stroke lesions.; p-values represent results from comparisons between ischemic lesions and contralateral normal appearing tissues.

Results

In acute/subacute cases, the ADC and AD are significantly decreased ($P < 0.01$) on the lesion side. The value of ADr (0.52 ± 0.20) is lower than ADCr (0.63 ± 0.20). Although the sRAr and RDr show the similar decreasing trend, the result is not statistically significant (Table 1).

In chronic cases, all parameters are significantly increased with the exception of sRAr ($p < 0.01$) (Fig. 2).

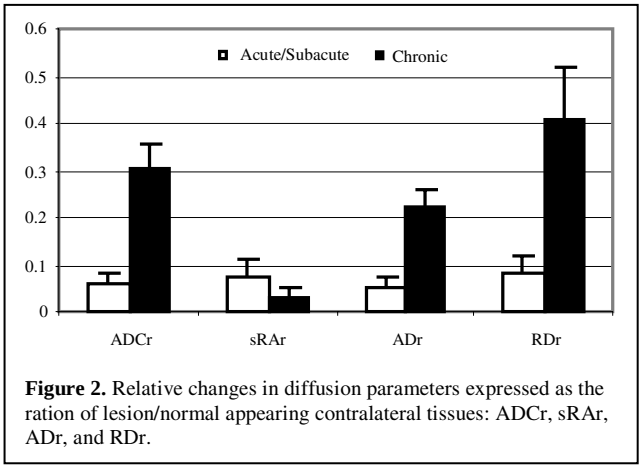

Figure 2. Relative changes in diffusion parameters expressed as the ration of lesion/normal appearing contralateral tissues: ADCr, sRAr, ADr, and RDr.

Discussions and conclusions

Both ADC and axial diffusivity significantly decreased in acute/subacute stroke lesions. The less significantly decreased sRA and radial diffusivity in these lesions was also observed. Axial diffusivity decreased more than that of ADC in white matter lesions. The previously reported studies applying axial and radial diffusivities suggest that the decreased axial and radial diffusivities observed herein may reflect the acute axonal injury in these acute stroke lesions. Increased axial and radial diffusivities in the chronic lesions may represent the loss of axonal and myelin integrity. In conclusion, the diffusion tensor derived directional diffusivities may potentially depict more detailed changes in the underlying microstructure of the white matter than does ADC in ischemic stroke. The clinical value of the application of DTI derived directional diffusivities remains to be further evaluated.

References

1.Song et al., Neuroimage 2005;26: 132-40. 2.Sotak CH, NMR Biomed. 2002;15:561-569. 3.Harris et al., J Magn Reson Imaging. 2004;20:193-200