Diffusion tensor markers for amyotrophic lateral sclerosis

A. M. Ulug[1], M. F. Beal[2], X. Mao[3], D. C. Shungu[3], S. Chan[3], M. X. Tang[4], H. Mitsumoto[4]

[1]Radiology, Weill Medical College of Cornell University, New York, NY, United States, [2]Neurology, Weill Medical College of Cornell University, New York, NY, United States, [3]Radiology, Columbia University, New York, NY, United States, [4]Neurology, Columbia University, New York, NY, United States

Introduction

Amyotrophic lateral sclerosis (ALS) is a progressive neuromuscular disease involving motor neurons. Most cases of ALS are sporadic and the cause is unknown. Degeneration of peripheral and central axons occurs in the white matter fiber tracts extending from the motor strip to the spinal cord (corticospinal tract). Diffusion tensor imaging has the capability to visualize the corticospinal tract and may determine its health by quantifying the diffusion anisotropy. Hence this imaging modality may have unique role in helping to diagnose this disease [1-4].

We have studied 33 patients with motor neuron diseases with different amount of upper motor neuron involvement and 8 controls using diffusion tensor imaging.

Methods

20 sporadic ALS patients, 3 familial ALS patients, 2 PLS patients, 8 PMA patients and 8 age-matched normal volunteers were included in this study. Patients are studied longitudinally at 3-month intervals. The MR imaging was performed on a 1.5T clinical MR scanner with a quadrature head coil. A diffusion-weighted single-shot EPI pulse sequence is used to collect the diffusion tensor images. Thirty 5-mm interleaved slices are acquired to cover the entire brain from motor cortex to pyramidal decussation. The imaging parameters included, TR=10 s, TE=100 ms, image matrix=128x128, FOV=220 mm. Diffusion was measured in twenty-six non-collinear gradient directions. In addition 6 images without diffusion weighting are acquired. The maximum b-value per gradient axis was of 820 s/mm^2. With 30 slices and 32 images per slice, a total of 960 diffusion-weighted images are collected in 5 minutes and 20 seconds.

The components of diffusion tensor (diffusion maps) were then calculated. Using the tensor components an orientationally invariant diffusion constant (D_{av}=Trace{D}/3) and an orientationally-independent diffusion anisotropy map (UA_{surf}) was calculated for each pixel [5]. The health of corticospinal tract was evaluated at the level of basal ganglia by measuring the average diffusion constant and diffusion anisotropy of the posterior limb of internal capsule (PLIC) using one region of interest at each hemisphere. The results from the right and left PLIC were then averaged.

Results

In all patient groups diffusion anisotropy were decreased and average diffusion constant were increased compared to the normals (Table 1). There was a significant correlation with increased diffusion and decreased anisotropy (Fig.1). By plotting D_{av} v.s diffusion anisotropy, diffusion tensor imaging was able to rank the patient groups according to their upper motor neuron involvement.

Discussion

The corticospinal tract is a major white matter fiber tract in the brain connecting the motor cortex to the spinal cord. The disease process damages the upper motor neuron connections in this fiber bundle hence decreases the restriction upon water diffusion. The overall diffusion as measured by (D_{av}) increases and the directionality of diffusion as measured by diffusion anisotropy decreases. Utilization of diffusion tensor imaging in diagnosing motor neuron diseases may help to identify various sub-groups which has widely differing disease progression rate, hence help in clinical patient management.

Acknowledgment

Supported in part by R01 NS41672-01

References

[1] Ellis CM et al. Neurology 1999; 53: 1051-1058. [2] Ulug AM et al. AJNR 1999; 20: 1044-1048. [3] Ulug AM et al. Proc. Intl. Soc. Mag. Reson. Med 2000; 8: 87. [4] Ulug AM et al. Proc. Intl. Soc. Mag. Reson. Med 2000; 8: 777. [5] Ulug AM et al. JMRI 1999; 9: 804-813.

Table 1. Diffusion measurements of patients and normal controls

	PLS n=2	fALS n=3	ALS n=20	PMA n=8	NORMAL n=8
D_{av} (10^{-5}cm^2/s)	0.656	0.775	0.677	0.669	0.652
Anisotropy (UA_{surf})	0.156	0.093	0.128	0.119	0.168

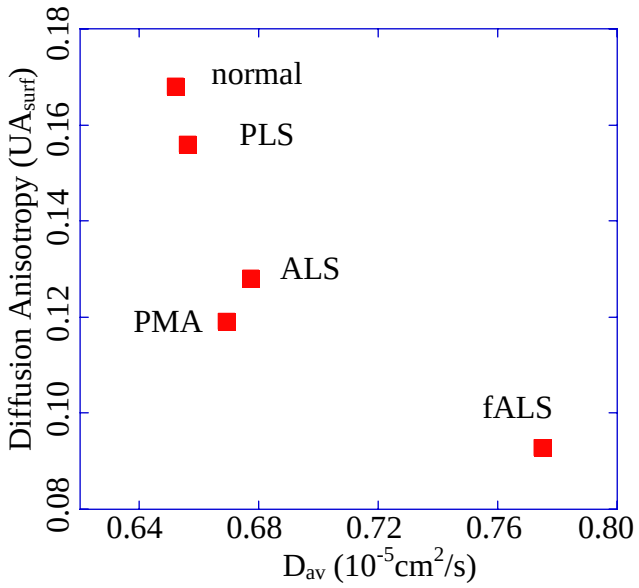

Fig 1. Diffusion anisotropy values are plotted against the average diffusion constant in each subject group. There is a strong correlation with increased diffusion constant and decreased diffusion anisotropy.