Effect of Central Nervous System Involvement in Systemic Lupus Erythematosus Patients : Examination Using Diffusion Parameters and Volumetric Measurement

S-P. Lee[1], J-Z. Cheng[2], W-Y. Chiang[3], C-M. Chen[2], and K-L. Wang[1]

[1]Department of Medical Imaging and Technology, Far Eastern Memorial Hospital, Taipei, Taiwan, [2]Institute of Biomedical Engineering, National Taiwan University, Taipei, Taiwan, [3]Center for Optoelectronic Biomedicine, National Taiwan University Medical College, Taipei, Taiwan

Introduction:

None of systemic lupus erythematosus (SLE) studies examined diffusion tensor imaging (DTI) and volumetric measurement in the same groups [1-4]. This paper aimed to investigate the effect of central nervous system (CNS) involvement in SLE patients on two diffusion parameters, i.e., fractional anisotropy (FA) and mean diffusivity (MD), and one volumetric measurement, i.e., volume. To accurately define the corpus callosum boundaries, an automatic segmentation algorithm, cell-competition method [5], was adopted to delineate the boundaries of the corpus callosum on mid-sagittal FA maps to calculate FA, MD and volume of corpus callosum.

Materials & Methods:

The participants included 10 SLE patients with a history of CNS involvement (mean±SD=46.50±17.32) (8f/2m), 12 SLE patients without CNS involvement (mean±SD=38.25±10.31) (11f/1m) and 22 healthy volunteers (mean±SD=41.59±14.93) (20 f/2m). All images were acquired on a 1.5T MRI system (Sonata). DTI was performed using diffusion single-shot echo-planar imaging (EPI) sequence, TR/TE = 8900/95 ms, image matrix size = 128 x 128, FOV= 280 x 280 mm^2, and two b-values (0 and 1000 s/mm^2). DTI encoding scheme with 13 icosahedra-oriented steps were used to obtain 55-60 slices. The scan time was approximately 13 minutes. The normalized mutual information (NMI) method built-in SPM2 was used to correct the spatial distortion. To compare brain sizes of the two individuals, DTI null image were normalized to the MNI T2 template with affine transformation. The deformation matrix of the affine transform then applied to the FA maps.

Cell competition procedure had 5 crucial steps, included Gaussian-filter, Sobel-filter, first-pass watershed transformation, second-filter watershed transformation and cell-competition algorithm to automatically segment corpus callsoum boundaries on mid-sagittal T1-weighted images and FA maps. To evaluate the feasibility of the cell-competition algorithm in attaining the corpus callosum boundaries, the boundaries of 10 normal females' T1-weighted images derived by the cell-competition algorithm were compared to the manually-delineated boundaries demarcated by 4 observers. Two assessments were performed. The first one was to assess if the distance between the computer-generated and manually-delineated boundaries was within the 95% confidence interval of the inter-observer's distance. The second one was to test if the areas defined by computer-generated and manually-delineated boundaries were highly correlated by using Pearson correlations.

One-way analysis of covariance (ANCOVA) was used to examine group differences in FA, MD and volume with age as a covariate in SPSS software. For multiple comparisons, Bonferroni correction was employed to test if has a significant change in each modality.

Results:

To demonstrate the effectiveness, Fig. 1(left) shows a slice of T1-weighted image. As illustrated by a red contour in Fig. 1(right), the boundary derived by the cell-compeition algorithm reasonably coincides with the visually perceived boundary. Table1 further shows that the percentages that the distance between the computer-generated and manually-delineated boundaries is within the 95% CI of the inter-observer's distance are 90 %, 90 %, 80 %, and 70 %, respectively. The Pearson's coefficient between the areas defined by the computer-generated boundaries and the average manual-drawn boundaries is 0.996. It corroborates that the cell competition algorithm may derive the corpus callosum boundaries that are comparable to manually delineated boundaries.

The results of our segmentation procedure in a SLE patient with CNS involvement, a SLE patient without CNS involvement and a healthy volunteer are shown in Fig.2. Our segmentation procedure successfully identifies corpus callosum boundaries on these 3 groups of mid-sagittal FA maps. For multiple comparisons, Table. 2 shows Bonferroni correction results. The SLE patients with CNS involvement have significantly lower FA (P=0.000) and smaller volume (P=0.000) of corpus callosum than those for the SLE patients without CNS involvement. The SLE patients with CNS involvement have significantly lower FA (P=0.000), higher MD (P=0.030) and smaller volume (P=0.039) of corpus callosum than those for healthy controls. The SLE patients without CNS involvement have no significantly different FA, MD and volume of corpus callosum than those for healthy controls.

Figure.1. performs this algorithm on T1-weighted images (left) that goes through 5 major steps to obtain corpus callsoum boundary by using red line representation (right).

Observer	CO	IO	CO-IO	95% CI	P (%)
1	0.9082	1.0491	-0.1409	-1.1874, 0.9056	90 %
2	0.7559	0.9757	-0.2198	-1.3514, 0.9118	90 %
3	0.9166	0.9469	-0.0303	-1.2977, 1.2371	80 %
4	0.6016	0.8457	-0.2441	-0.9101, 0.4219	70 %

Table.1. The mean compute-to-observer distance (CO) vs. mean maximum interobserver distances (IO) on 10 T1-weighted images, P=percentage of cases within the interobserver range.

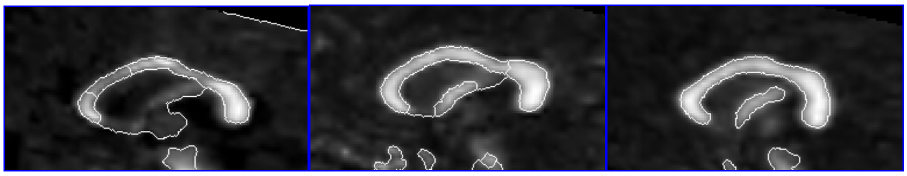

Fig.2. performs this algorithm to capture corpus callosum boundaries on mid-sagittal FA maps that included a 38 year-old female SLE patient with CNS (left), a 38 year-old female SLE patient without CNS (middle) and a 42 year-old normal female (right).

Group	1. N=10	2. N=12	3. N=22
CC	SLE with CNS	SLE without CNS	Controls
FA	0.578±0.087	0.690±0.026	0.698±0.024
Pairwise comparisons	P_{13}=0.000*	P_{12}=0.000*	P_{23}=1.000
MD (10^{-3}mm^2/s)	0.869±0.150	0.790±0.265	0.701±0.027
Pairwise comparisons	P_{13}=0.030*	P_{12}=0.902	P_{23}=0.341
Volume (mm^3)	3550.86±485.58	3795.99±393.05	4083.34±551.33
Pairwise comparisons	P_{13}=0.039*	P_{12}=0.000*	P_{23}=0.186

Table.2. shows Bonferroni correction results, each modality has a significantly different between two groups on corpus callosum by using a red asterisk to highlight.

Conclusion:

It is concluded that the CNS involvement would lead to the change of FA and volume of the corpus callosum for SLE patients. Moreover, the SLE patients with CNS involvement will have significantly different FA, MD and volume of the corpus callosum than those in the control group.

Reference:

[1] Appenzeller et al. NeuroImage, 2007; 34:694-701. [2] Zhang et al. MRI, 2007; 25: 399-405. [3] Rocca et al. NeuroImage, 2006; 30: 478-484. [4] Appenzeller et al, Arthritis Rheum, 2005; 52: 2783–2789. [5] Chen et al. UMB, 2005; 31:1647-1664.