Preliminary study on multiple sclerosis of the cervical spinal cord by using MR diffusion tensor imaging

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Diffusion tensor imaging (DTI) has been successfully applied in the quantitative assessment of various brain disorders, but the clinical evaluation of the spinal cord with DTI was limited because of the small caliber of the spinal cord, the artifact caused by cerebral spinal fluid (CSF), respiration, and heart beat, the inhomogeneity caused by adjacent bony structures, and relative long examination time. In this study, a practical DTI sequence for the cervical spinal cord was investigated, and apparent diffusion coefficient (ADC) map and fractional anisotropy (FA) map with acceptable image quality were acquired, and ADC value, FA value, and eigenvalues were calculated. The DTI scanning protocol was then applied in the assessment of the cervical spinal cord in patients with multiple sclerosis (MS).

Methods

Thirty-six consecutive volunteers and 12 patients with clinically proved MS of the cervical spinal cord were included in this study. The normal control subjects included 19 males and 17 females, and their age ranged from 17 to 62 years (mean 43 years). The patients included 4 males and 8 females, and their age ranged from 15 to 64 years (mean 48 years). Informed consent approved by the institutional review board was obtained from each subject.

A superconductive 1.5T MR scanner (Twin Speed, GEMS, Milwaukee) was employed and the phase-array CTL coil was used. Conventional sagittal FRFSE T2WI, T1FLAIR T1WI, and axial FRFSE T2WI of the cervical cord were obtained in all patients and normal controls. The slice thickness of the sagittal plane was 3 mm and the gap was 0. DTI was then performed in the same sagittal planes with single shot SE-EPI sequence (TR=6000 ms, TE=102 ms, b value=400 s/mm^2, the number of diffusion sensitive gradient direction=6, NEX=3, and the matrix=128×128). 7 sagittal planes were scanned and a total of 49 images were obtained, and the scan time for DTI was 1 min 48 sec.

ADC and FA maps were acquired on the workstation by using FuncTool software. ADC, FA, and eigenvalues (λ_1, λ_2, and λ_3) were measured by using ROI containing 20~30 pixels. For normal controls, ROI was placed in the cord at C1~C7 vertebral body levels, while for MS patients, ROI was placed in the abnormal areas. ADC and FA maps were evaluated and ROI measurements performed by two neuroradiologists blinded to the diagnosis. Then the data were statistically analyzed.

Results

In normal controls, the cervical spinal cord was demonstrated as dark blue and CSF as red on ADC map (Fig.1), and the cord as red and CSF as light green on FA map (Fig.2). The measurement values of ADC, FA, λ_1, λ_2, and λ_3 were (914.4±82.6) 10^{-6}mm^2/s, 0.594±0.052, (1585.1±130.1) 10^{-6}mm^2/s, (559.8±66.5) 10^{-6}mm^2/s, and (613.3±128.7) 10^{-6}mm^2/s, respectively. In MS patients, inhomogeneous light blue areas were revealed in the cord on ADC map (Fig.3) and inhomogeneous yellow areas were detected on FA map (Fig.4). The abnormal areas on both ADC and FA maps were evidently larger than the abnormal areas on T2WI (Fig.5) in 9 cases. The measurement values of ADC, FA, λ_1, λ_2, and λ_3 in MS patients were (1473.7±227.8) 10^{-6}mm^2/s, 0.468±0.044, (2024.1±283.3) 10^{-6}mm^2/s, (1151.8±146.1) 10^{-6}mm^2/s, and (1231.0±360.9) 10^{-6}mm^2/s, respectively. ADC, λ_1, λ_2, and λ_3 in MS patients were significantly higher than those in normal controls (P<0.05), whereas FA in MS patients was statistically lower than that in normal controls (P<0.05).

Discussion

Clinical application and assessment of the spinal cord with DTI has been a challenge because of the small cord size and various influencing factors. However, DTI of the cervical spinal cord has been successfully performed in previous studies [1~3], but it needs various compensation techniques and the examination is time consuming. In this study, we acquired aceptable DTI images within a relative short time, and the results are consistent with the anatomic fact, i.e. the normal cervical spinal cord is a cylinder-like tissue with high anisotropic diffusion. Of the 12 patients, 9 showed more abnormal areas on ADC and FA maps than on T2WI, suggesting that T2WI may underestimate MS lesions. Since the demyelination and associated edema of MS plaques can cause increased ADC and decreased FA, ADC and FA maps may be more sensitive than T2WI in demonstrating the subtle changes caused by the plaques, indicating that DTI is a promising technique in futher studies of MS.

References

[1] Clark CA, et al. Magn Reson Med, 1999, 41: 1269-1273
[2] Murphy BP, et al. J Magn Reson Imaging, 2001, 13: 949-953
[3] Droogan AG, et al. Magn Reson Imaging, 1999, 17: 653-661

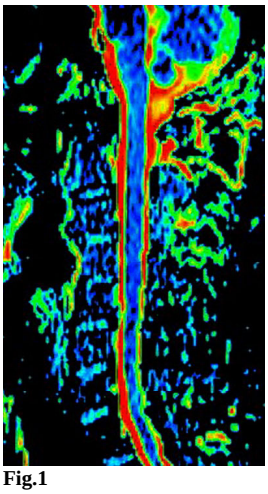

Fig.1

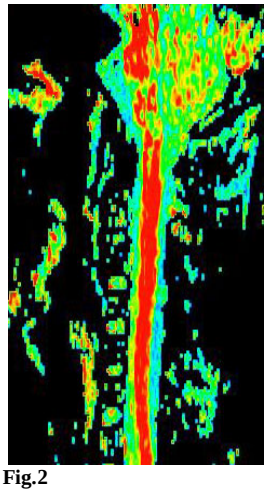

Fig.2

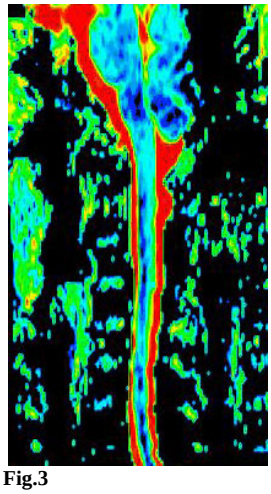

Fig.3

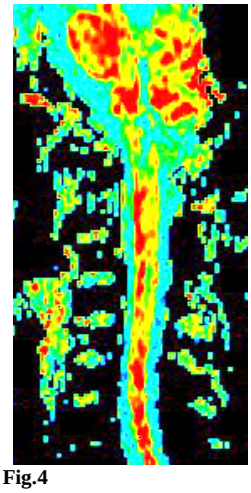

Fig.4

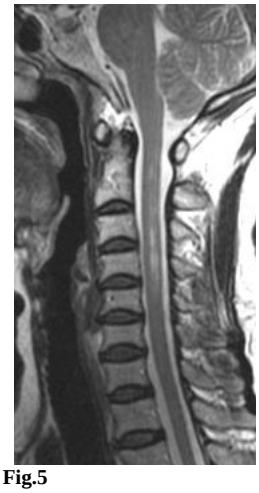

Fig.5

Figure 1: ADC map in normal subject. The cervical spinal cord was demonstrated as relative homogeneous dark blue and CSF as red.
Figure 2: FA map in normal subject. The cervical spinal cord was demonstrated as homogeneous red and CSF as light green.
Figure 3: ADC map in a MS patient. Inhomogeneous light blue areas were detected in the cord, indicating increased ADC in those areas.
Figure 4: FA map in the same patient as in Figure 3. Inhomogeneous yellow areas representing decreased FA were revealed.
Figure 5: Conventional T2WI in the same patient as in Figure 3. The extent of the high signal intensities within the cord was less than the abnormal areas on ADC and FA maps.