

# Comparative Study of Syringomyelia and Myelomalacia of the Cervical Spinal Cord by Using MR Diffusion Tensor Imaging

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Although there are some technical difficulties in applying diffusion tensor imaging (DTI) in the spinal cord, DTI has been successfully acquired in the cervical spinal cord [1, 2], and quantitative assessment including apparent diffusion coefficient (ADC), fractional anisotropy (FA), and eigenvalues was successfully performed in patients with multiple sclerosis of the cervical cord [3]. In this study, DTI was employed for the comparative study of syringomyelia and myelomalacia of the cervical spinal cord, and ADC value, FA value, and eigenvalues were quantitatively assessed to explore the possible differences between syringomyelia and myelomalacia.

## Methods

Seven patients with syringomyelia and 12 patients with myelomalacia of the cervical spinal cord were included in this study. The patients with syringomyelia included 4 males and 3 females, and their age ranged from 23 to 58 years (mean 39 years). The patients with myelomalacia included 8 males and 4 females, and their age ranged from 26 to 54 years (mean 41 years). 36 volunteers included 19 males and 17 females, and their age ranged from 17 to 62 years (mean 43 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<sup>2</sup>, 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 ( $\lambda_1$ ,  $\lambda_2$ , and  $\lambda_3$ ) 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 patients with syringomyelia and myelomalacia, ROI was placed in the abnormal areas. ADC and FA maps were evaluated and ROI measurements were performed by two neuroradiologists blinded to the diagnosis. Then the data were statistically analyzed.

## Results

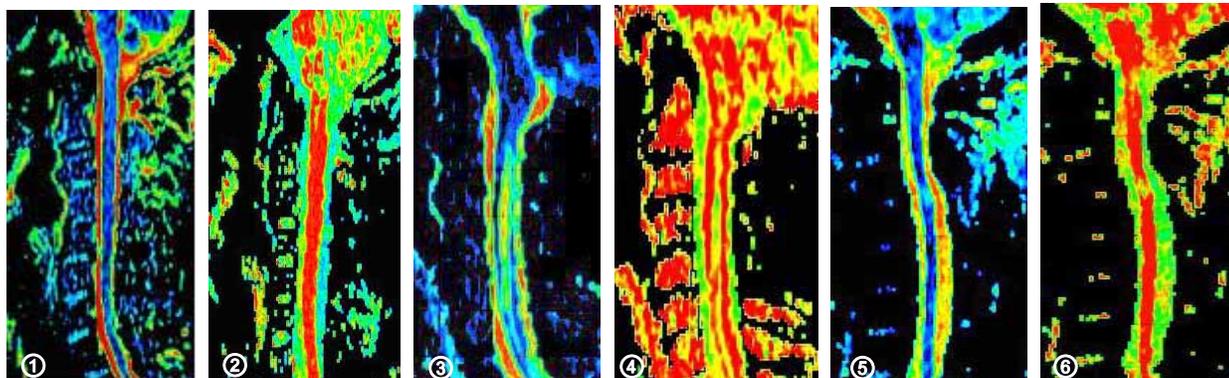
In normal controls, the cervical spinal cord was demonstrated as dark blue and CSF as red on ADC map (Fig.1), and the cord as red and CSF as light green on FA map (Fig.2). The measurement values of ADC, FA,  $\lambda_1$ ,  $\lambda_2$ , and  $\lambda_3$  were  $(914.4 \pm 82.6) 10^{-6} \text{mm}^2/\text{s}$ ,  $0.594 \pm 0.052$ ,  $(1585.1 \pm 130.1) 10^{-6} \text{mm}^2/\text{s}$ ,  $(559.8 \pm 66.5) 10^{-6} \text{mm}^2/\text{s}$ , and  $(613.3 \pm 128.7) 10^{-6} \text{mm}^2/\text{s}$ , respectively. In syringomyelia patients, linear inhomogeneous yellow and light green signals were demonstrated within the cord on ADC map (Fig.3) and green and yellow signals were detected on FA map (Fig.4). The abnormal signals within the cord were similar to those of CSF on both ADC and FA maps. The measurement values of ADC, FA,  $\lambda_1$ ,  $\lambda_2$ , and  $\lambda_3$  in syringomyelia were  $(3147.4 \pm 556.6) 10^{-6} \text{mm}^2/\text{s}$ ,  $0.204 \pm 0.018$ ,  $(4161.8 \pm 625.5) 10^{-6} \text{mm}^2/\text{s}$ ,  $(3591.8 \pm 752.6) 10^{-6} \text{mm}^2/\text{s}$ , and  $(3355.2 \pm 664.8) 10^{-6} \text{mm}^2/\text{s}$ , respectively. ADC,  $\lambda_1$ ,  $\lambda_2$ , and  $\lambda_3$  in syringomyelia patients were significantly higher than those in normal controls ( $P < 0.01$ ), whereas FA was statistically lower than that in normal controls ( $P < 0.01$ ). In patients with myelomalacia, the foci within the cord were revealed as light blue on ADC map (Fig.5) and green on FA map (Fig.6). The ADC, FA,  $\lambda_1$ ,  $\lambda_2$ , and  $\lambda_3$  values in myelomalacia were  $(1512.4 \pm 450.2) 10^{-6} \text{mm}^2/\text{s}$ ,  $0.408 \pm 0.086$ ,  $(2229.3 \pm 417.2) 10^{-6} \text{mm}^2/\text{s}$ ,  $(1416.0 \pm 379.1) 10^{-6} \text{mm}^2/\text{s}$ , and  $(1401.5 \pm 589.2) 10^{-6} \text{mm}^2/\text{s}$ , respectively. ADC,  $\lambda_1$ ,  $\lambda_2$ , and  $\lambda_3$  in myelomalacia patients were significantly higher than those in normal controls ( $P < 0.05$ ), while FA was statistically lower than that in normal controls ( $P < 0.05$ ). In addition, no statistical differences were found among  $\lambda_1$ ,  $\lambda_2$ , and  $\lambda_3$  in syringomyelia ( $P > 0.05$ ), but  $\lambda_1$  was significantly higher than  $\lambda_2$  and  $\lambda_3$  in myelomalacia ( $P < 0.05$ ). ADC in syringomyelia was higher than that in myelomalacia ( $P < 0.05$ ), and FA in syringomyelia was lower than that in myelomalacia ( $P < 0.05$ ).

## Discussion

Both syringomyelia and myelomalacia demonstrate low signal on T1WI and high signal on T2WI, and generally it is not difficult to differentiate the two disease entities based on the shape, extent, and location of the lesion. DTI with acceptable image quality was employed in this study to investigate the possible difference between syringomyelia and myelomalacia, and the result showed that DTI can not only reveal the abnormal changes in both syringomyelia and myelomalacia, but also provide the parameters that make quantitative analysis possible. Although ADC,  $\lambda_1$ ,  $\lambda_2$ , and  $\lambda_3$  were higher and FA was lower in both diseases compared with those of normal controls, ADC, FA, and eigenvalues showed differences between syringomyelia and myelomalacia, which was consistent with the different pathological mechanisms, i.e. the syringomyelia represents the dilated central canal of the cord which contains CSF (very high ADC, very low FA) and no cellular components (no differences among  $\lambda_1$ ,  $\lambda_2$ , and  $\lambda_3$ ), whereas myelomalacia is a secondary liquification in the cord parenchyma which contains increased free-water (high ADC, low FA) and partly destructed axon and myelin components ( $\lambda_1 > \lambda_2$  and  $\lambda_3$ ).

## References

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- [2] Xu D, et al. Magn Reson Imaging, 2004, 22: 751-759
- [3] Ma L, et al. ISMRM, 2005, 182



**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 syringomyelia patient. Linear yellow and light green signals were detected in the central canal of the cord, indicating increased ADC.

**Figure 4:** FA map in the same patient as in Figure 3. Linear green and yellow signals in the central canal representing decreased FA were revealed.

**Figure 5:** ADC map in a myelomalacia patient. Light blue area was detected in the cord, indicating increased ADC.

**Figure 6:** FA map in the same patient as in Figure 5. Green area representing decreased FA was demonstrated in the cord.