Diffusion anisotropy in myelin defficient rat spinal cord by high b value q-space diffusion imaging

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Synopsis

The origin and relative importance of myelin in determining water diffusion anisotropy is still under debate. To this end T_1 and high b-value q-space diffusion MRI was performed on excised myelin defficient (*md*; N=6) and age-matched control spinal cords (N=6). Higher diffusivity was found in the white matter (WM) of the *md* spinal cords than the WM of age-matched control spinal cords. However, the anisotropy index computed for both groups was found to be similar. These results suggest that myelin, under the experimental conditions used, is not the main determinant of water diffusion anisotropy in the present spinal cord preperations.

Introduction

Anisotropic water diffusion was observed in central nervous system (CNS) tissues such as the brain and spinal cord more than a decade ago (1-2). Diffusion tensor imaging (DTI) uses this water diffusion anisotropy to trace fibers and diagnose CNS abnormalities (3). However, the origin and relative importance of different structural components in determining this water diffusion anisotropy is still not totally clear (4). To address this problem, we used high b-value (or high q value) diffusion weighted MRI to study the role water diffusion characteristics of *md* and control rat spinal cords. These *md*-rats are X-linked recessive Wistar rat mutants, which show a near-total lack of myelination in their CNS (5).

Methods

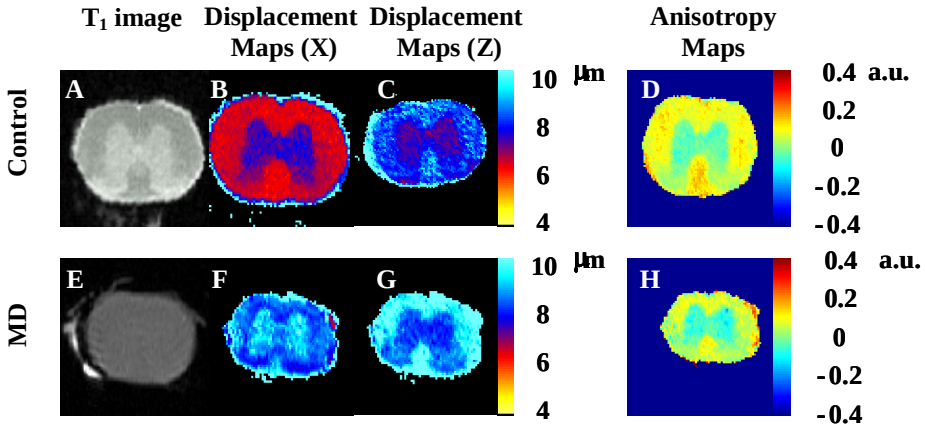
The study was performed on twenty-one day old *md* (N=6) and control (N=6) rat spinal cords fixed in 4% paraformaldehyde. MRI experiments were performed on an 8.4T NMR spectrometer (Bruker, Germany) equipped with a micro5 gradient probe capable of producing pulse gradients of up to190 gauss/cm in each of the three directions. We acquired multislices, transverse T_1-weighted images (TR/TE=700/15ms) and diffusion-weighted data with a slice thickness of 1.35 mm and a FOV of 8.5x8.5 mm. Diffusion-weighted data were acquired using the stimulated-echo diffusing imaging sequence with the following parameters: TR/TE=2000/30 ms, Δ/δ=50/2 ms, G_{max}=50 G/cm resulting in a b_{max} and q_{max} of 3.53 $x10^5$ s/cm^2 and 426 cm^{-1}, respectively. Diffusion was measured perpendicular and parallel to the long axis of the spine. In each experiment 16 b-values were acquired, and the displacement, probability and anisotropy maps were calculated as previously described (6-7). The temperature in the magnet was maintained at 25±0.1^{0}C throughout the duration of the experiments.

Results

A clear contrast between white matter (WM) and gray matter (GM) was observed in the T_1-weighted images of the control spinal cords (Fig. 1A), while no such contrast was observed in the T_1-weighted images of the *md* spinal cords (Fig. 1E). However, the contrast between WM and GM is clear in all the q-space DWI maps of both rat groups. Displacement maps for diffusion measured perpendicular (x) and parallel (z) to the long axis of the spine of representative control and *md*-spinal cords are shown in Figs. 1B-C and 1F-G, respectively. The differences between the two mice groups are very clear in the displacement and probability maps. The mean displacements of the WM in the *md* spinal cords were higher than those of control spinal cords and found to be 7.44±0.50 µm and 6.58±0.11 µm in the x direction and 9.47±0.73 µm and 8.69±0.37 µm in the z direction, respectively. The same trends were observed in the q-space probabilities maps (data not shown). The anisotropy maps of representative control and *md*-spinal cords are shown in Figure 1D and 1H, respectively. We found that the anisotropy maps of the control and *md*-spinal cords are not very different. For the entire groups studied, the mean anisotropies in the WM of the control and *md*-spinal cords were found to be 0.13±0.02 and 0.12±0.03 a.u., respectively.

Discussion

In this study we found that high b-value q-space displacement and probability maps are sensitive to a lack of myelination in the CNS, while the anisotropy map seems to be less sensitive and did not show a statistically significant difference between the two rat groups. These results are in line with a recent report of Gulani et al. who found higher diffusivity in excised *md*-spinal cords than age-matched controls (8) but differ in that our anisotropy index was not different in the two groups, under the experimental conditions used. These results suggest that, in the present spinal cord preparations under the protocol used and where diffusion anisotropy is not very high due to the young age of both *md* and control rats, myelin is not the main determinant of water diffusion anisotropy.



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