q-Space MRI and DTI of excised myelin deficient rat brains

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Introduction

Water diffusion in neuronal tissues was found to be anisotropic more than a decade ago.[1] Despite of the widespread use of diffusion imaging techniques, especially the DTI method, the relative importance of myelin in determining the observed water anisotropy under different experimental conditions is still under debate.[2] Although the DTI technique is the most useful DWI method to characterize white matter characteristics and disorders, it's based upon a single component analysis[3] while it is well know that at sufficient high diffusion weighting, more than one diffusion component can be observed in neuronal tissues.[4] Recently, High b-value q-space diffusion MRI, which emphasizing the slow diffusing component, was used to obtain structural information in neuronal tissues.[5] This methodology was reported to be sensitive to lack of myelin and myelin disorders.[6] In the present study we used high b-value q-space diffusion MRI and conventional DTI to characterize, for the first time, the diffusion characteristics of myelin deficient (md) rat brains and their age-matched controls.

Methods

MRI experiments were performed using a 7T/30cm BioSpec system (Bruker, Germany) equipped with a BGU20 gradient system capable of producing pulse gradients of 40Gcm^{-1} in each of the three dimensions. Formalin-fixed brains of 21-day old md (N=4) and control (N=4) rats were used in this study. Eight continuous 1mm slices were acquired with a field of view (FOV) of 2.56×2.56cm and 256×128 digital resolution reconstructed to 256×256 matrixes. The MRI protocol included high b-values q-space MRI and conventional DTI acquired in 6 directions using the stimulated echo (STE) diffusion sequence. In order to determine the optimal experimental parameter to distinguish between the two groups three different Δs (i.e. 40, 100 and 200ms) were used to acquire the diffusion MR data. The following parameters were used in the study: TR/TE/Δ/δ=1800/20/200/4ms with four averages. The q-space MR images were acquired by incriminating the diffusion gradient from 0 to 30Gcm^{-1} in 16 steps for all 6-directions resulting in a maximal b- and q-values of 18440s/mm^2 and of 511cm^{-1}, respectively. The DTI data sets were acquired with the same parameters and b-max of 2500 s/mm^2.

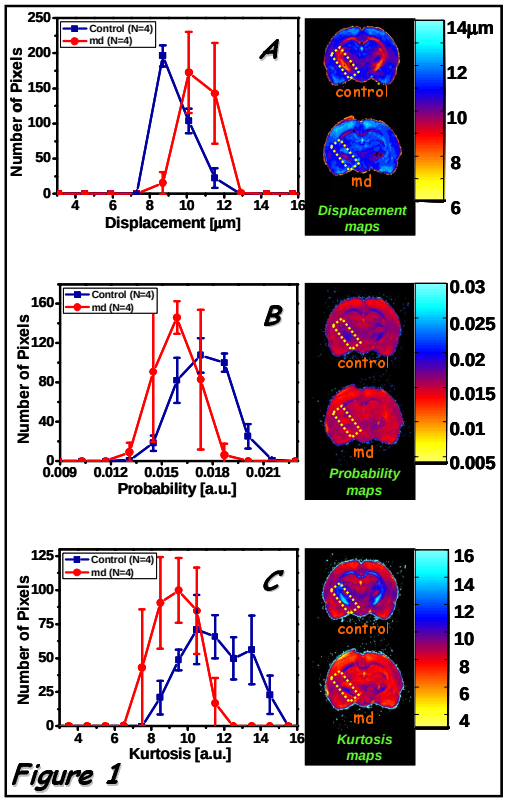

Figure 1

Results and Discussion

Figure 1 depict the displacement, probability and kurtosis maps, obtained from the q-space diffusion MRI experiments of representative md and control brains at a diffusion time of 200ms. Quantitative ROI analyses of WM rich area of all three parameters are also shown for the two investigated groups. The displacement maps represent the minimum displacement value found for the six diffusion direction sampled. The probability maps depict the maximum probability for zero displacement and the kurtosis maps point out the maximum kurtosis values obtained from the six diffusion directions used in the study. Figure 1A shows that in WM areas (limited in yellow boxes) the displacement values are smaller for the control brains as compared to the md tissues. Figures 1B and 1C show that in the WM of the md brains the probability for zero displacement and kurtosis are decreased. These results imply that the myelin sheaths do affect the q-space diffusion MRI results in WM reach areas.

Figure 2 shows the FA maps as well as the quantitative ROI analysis of the same WM reach area obtained from conventional DTI protocol. The data clearly show that there is no significant difference between the FA of the md and their age-match control brains. This implies that FA blurs the differences between the two groups. We also examined another WM ROI, the corpus callosum, and found the same trends for all investigated parameters (data not shown). The differences between the samples were also examined by histological images.

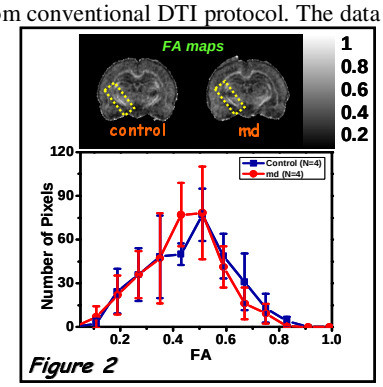

Figure 2

Summary

This study clearly demonstrates that lack of myelin affects, significantly, the diffusion indices obtained from high b-value q-space DWI. We found that all three indices extracted from the q-space MR data (i.e. displacement probability and kurtosis) depend on the myelin content although to a different extent. This study also implies that FA blurs the differences between the two groups and one may consider the use of high b-value q-space DWI in order to achieve better distinction between md and normal neuronal tissues.

References

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