In vivo Spinal Cord Diffusion Tensor Imaging of Rodent at 9.4T

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Introduction

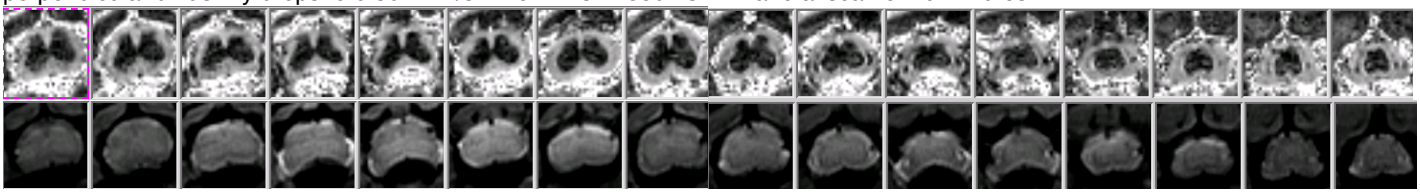
Spinal cord diffusion tensor imaging (DTI) is an important tool for the study of neurodegenerative defects in Amyotrophic Lateral Sclerosis (ALS) mouse model[1] as well as in mouse/rat model of spinal cord injury[2]. Unlike spinal cord DTI in human studies, rodent studies are notoriously difficult due to the size of the spinal cord as well as severe respiratory artifacts. In addition, recent studies are focused on two-dimensional slice selective acquisition[1,3,4] with 0.5 to 0.8mm in mouse or rat[5], which implies a rather large slice gap between images and hamper our ability to study focal neurodegeneration in the spinal cord. In this paper, we present a three-dimensional segmented EPI technique that partially overcome these limitations and we demonstrate the feasibility of spinal cord DTI in mouse and rat.

Methods

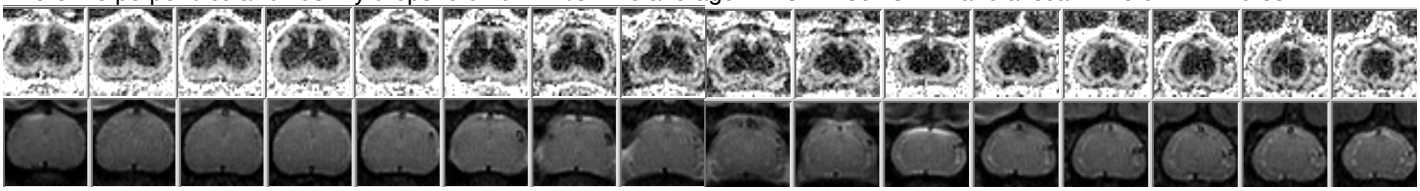
In vivo DTI studies were performed on Fisher 344 rats (n=3, 6-7 week old) and adult C57B6 mice (n=3) on a 9.4T Bruker scanner running Paravision 5.1. A 72-mm inner diameter quadrature volume coil was used as a RF transmitter and a 20 mm x 20mm phase array coil was used as a RF receiver. Sagittal T2-weighted RARE sequence was used to obtain the anatomical images of the spine. A 3D segmented spin-echo echo-planar sequence was used to acquire the axial DTI dataset at the resolution of 100 μm × 100 μm × 500 μm with respiratory gating and spectral fat saturation. The detailed imaging parameters are TR/TE= 2200ms to 2600ms/29.15ms, FOV=12.8 x 12.8 x18.0 mm^3, diffusion gradient duration (δ) of 4 ms and gradient separation (Δ) at 9.13 ms and b-value of 700 s/mm^2. Six orthogonal diffusion sensitizing gradient orientations and two b-value=0 images were acquired. DTI-Studio (www.mristudio.org) was used to generate the DTI parametric maps. Prior to diffusion tensor calculation, image registration was performed using AIR[6] using a 6-parameter rigid body transform. All images were coregistered together by minimizing the standard deviation of the ratio between diffusion images and the b0 images. Parallel diffusivity is the first eigen value and perpendicular diffusivity is the average of the second and third eigen values.

Results

Representative fractional anisotropy (FA) maps of mouse spinal cord at lumbar level and below are shown in the figure below with matching b0 images under it. The mean FA values, parallel diffusivity and perpendicular diffusivity are 0.77, 2.15 mm^2/s and 0.72 mm^2/s respectively in the white matter (WM) and 0.36, 0.92 mm^2/s and 0.59 mm^2/s in the gray matter (GM). The values are similar to those acquire using the slice selective acquisition technique in the literature.[1,3,4] There is a ~100 μm zone between GM and WM where the perpendicular diffusivity drops to 0.30 mm^2/s. The TR is ~2550ms with a total scan of 49 minutes.



Representative fractional anisotropy maps of rat spinal cord at lumbar level are shown in the figure below with matching b0 images under it. The mean FA values, parallel diffusivity and perpendicular diffusivity are 0.75, 2.78 mm^2/s and 1.01 mm^2/s respectively in the white matter (WM) and 0.38, 1.17 mm^2/s and 0.78 mm^2/s in the gray matter (GM). There is a 150-200 μm zone between GM and WM where the perpendicular diffusivity drops to 0.49 mm^2/s. The average TR is ~2136ms with a total scan time of 41 minutes.



Conclusion

We demonstrated that high quality DTI studies of mouse and rat spinal cord with 3D segmented EPI technique. High quality respiratory gating is essential and a TR at or above 2500ms is desirable in order to obtain images with enough signal-to-noise ratio. The 20mm surface coil covers about 5 vertebrae in the mouse lumbar spine region and about 3 vertebrae in the rat lumbar spine region. High quality DTI measurements can be performed over a 13.3 mm region in the head-foot direction due to drop-off in surface coil sensitivity towards the coil edge. An elongated surface coil conforming to spine anatomy would be useful to improve the sensitivity & coverage.

References

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