Quantitative Imaging of White Matter Microstructure in Canine Brain Using High Angular DTI Microscopy

P. Wang[1,2], J-M. Zhu[1,2]

[1]Center for Biomolecular Imaging, Wake Forest University School of Medicine, Winston-Salem, NC, United States, [2]Department of Radiation Oncology, Wake Forest University School of Medicine, Winston-Salem, NC, United States

Introduction

MR Diffusion Tensor Imaging (MR-DTI) is a novel method to measure water diffusion anisotropy in biological tissues, and it is particularly useful for studying functional microanatomy in normal or diseased human brains. The same technology has also been applied to image animal brains *in vivo* or *ex vivo* [1, 2]. A recent work [3] from direct comparison of DTI measurements with *in vivo* mouse brains and *ex vivo* formalin-fixed mouse brains demonstrated that DTI results of fixed tissues were consistent with *in vivo* results. This offers a great new method to acquire extremely high spatial resolution DTI images, since there will be no motion artifacts involved and that the imaging times can be very long.

Our recent work and others have shown that multiple-angular diffusion encoding scheme provided much more accurate measurement and computation of diffusion anisotropy maps [4, 5]. The only drawback for such DTI experiments is the long acquisition time. Using formalin-fixed whole brain samples thus will overcome this problem and offer the opportunity to acquire high resolution DTI images with high accuracy. The specific aim of this study was to demonstrate the feasibility of acquiring microscopic DTI images, using whole brain canine models in combination with high angular diffusion-encoding technology on a 7T scanner.

Methods

Five canine whole brains were collected and provided by the Small Animal Clinical Services at the VA-MD Regional College of Veterinary Medicine, Virginia Tech. The animals died of natural causes; their brains were removed and immersed in 10% neutral buffered formalin for fixation. MRI Experiments were performed on a 7T magnet (Bruker, Ettlingen, Germany), with a gradient coil capable of generating maximum gradient amplitude of 400mT/m. A 7.5cm ID volume coil was used for RF transmitting and receiving. DWIs along 25 diffusion-encoding directions, including T2 weighted images, were acquired using the standard spin-echo diffusion encoding scheme, with the following parameters: TR = 1000ms, TE = 36 ms, b = 2500s/mm^2, and number of averages is 12. The slice geometry parameters were: slice thickness = 0.6mm, image matrix size = 256×256, FOV = 7.5×7.5 cm^2. The diffusion tensor matrix was computed using 25 DWIs, followed by the computation of fractional anisotropy (FA) index and fiber orientation.

Results and Discussion

Figure 1 shows three slices of high resolution DTI images from one of the fixed canine brains. The FA maps obtained with DTI using 25 diffusion-encoding directions showed extremely well-resolved fiber tracks, mainly from excellent FA contrasts between highly-organized and less organized tissue structures. Figure 2 shows an example of localized fiber orientation maps color-coded with diffusion tensor orientations. From these images, major and minor fiber tracks can be easily located due to much improved accuracy in tracking the orientation. In general, the images calculated from high resolution DTI experiments encoded with 25 directions showed much higher scalar contrast as well more accurate fiber structures. These all resulted from the better estimation of diffusion tensor model.

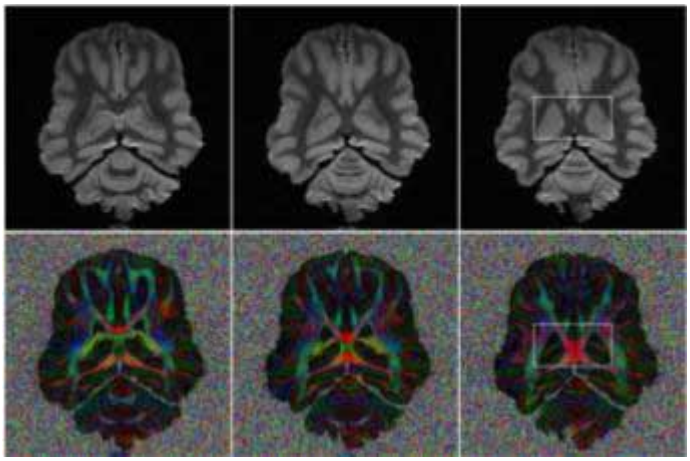

Fig.1 Anatomical slices and corresponding FA color maps.

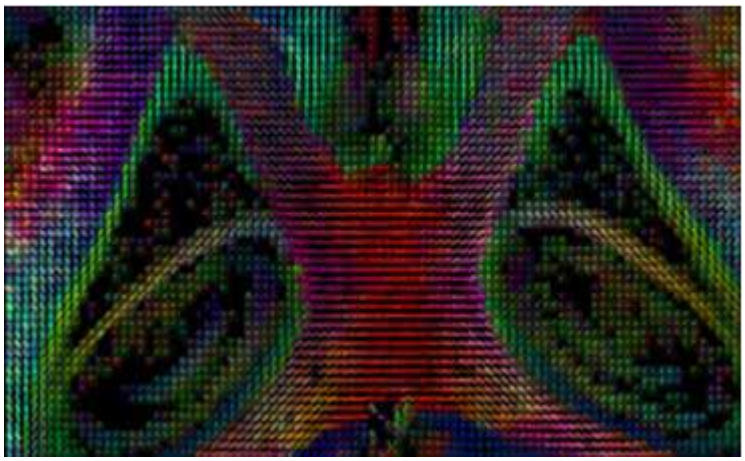

Fig.2 Fiber orientation map from selected ROI.

Conclusion

The current proposed method provided an accurate and yet quantitative imaging method to map white matter microstructure in fixed canine brain. Using this procedure, extremely high resolution microstructural images can be obtained. This will lead the most accurate method currently available to study functional microanantomy in brains, in particular, of animal models.

References

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