Quantitative Assessment of Tumor Microstructure in Canine Brain Using High Resolution DTI Microimaging

J-M. Zhu[1], P. Wang[1], J. L. Robertson[2], J. H. Rossmeisl, Jr.[2], M. E. Robbins[1], E. G. Shaw[1]

[1]Wake Forest University School of Medicine, Winston-Salem, NC, United States, [2]Virginia-Maryland Regional College of Veterinary Medicine, Blacksburg, VA, United States

Introduction

Diffusion tensor magnetic resonance imaging (DTI) is a recent imaging technique capable of mapping tissue microstructures. It thus has been found wide spread applications in the central nervous systems, for high resolution elucidation of white matter microanatomy. Images derived from DTI data have been suggested to be closely correlated with histological stains, as demonstrated in several correlation studies [1-3]. The quantitative measurement of DTI-derived data and images, including tensor orientations maps, further allows non-invasive assessment of white matter integrity related to tissue injury in various neurological disorders [4, 5].

The current technical limitation for quantitative DTI measurements includes long data-acquisition time, which introduces motion-related errors and artifacts. Image distortion is also severe due to magnetic field susceptibilities, in particular, for the cases using high field MRI systems. For imaging animal models, some recent work [3, 6] suggested that using formalin-fixed whole brains may provide a solution, since the DTI results of formalin-fixed tissues were consistent with *in vivo* results. This offers a great opportunity 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.

The purpose of this work was to demonstrate the potential of acquiring high resolution DTI images of fixed canine brains for studying spontaneously-developed brain tumor models. A high resolution diffusion encoding scheme using 25 directions was employed to acquire accurate and quantitative DTI data.

Methods

In total, seven canine whole brains were collected and provided for DTI imaging through the Small Animal Clinical Services at the Virginia-Maryland Regional College of Veterinary Medicine. Two of the animals were diagnosed to have neurobalstoma using clinical MRI exams. Following humane euthanasia by intravenous barbiturate overdosage, canine brains were removed and immersed intact in 10% neutral buffered formalin for fixation prior to imaging.

MRI Experiments were performed on a 7T small animal MR system (Bruker, Ettlingen, Germany), with a gradient coil capable of generating maximum gradient amplitude of 400mT/m. A 7cm ID volume coil was used for RF transmitting and receiving. DWIs along 25 diffusion-encoding directions, and T2 weighted images, were acquired using the standard spin-echo diffusion weighted pulse sequence, 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 = 6x6 cm^2. The diffusion tensor matrix was computed using the 25 DWIs, followed by the computation of fractional anisotropy (FA) index and fiber orientation.

Results and Discussion

Examples of DTI images, shown in orientation-color-coded FA maps, are displayed in Figure 1 for one of the fixed canine brains with tumor. The FA maps obtained with DTI using 25 diffusion-encoding directions showed extremely well-resolved fiber tracks, mainly from excellent FA contrasts between different tissue structures. Reduction in FA values can be seen in tumor core and major white-matter fiber tracts, due possible to tumor infiltration. Major affected fiber tracts are diverged both into different shape and fiber orientations. Using this high resolution technique, detailed microstructure can be detected both intra-tumoral and from the surrounding tissues.

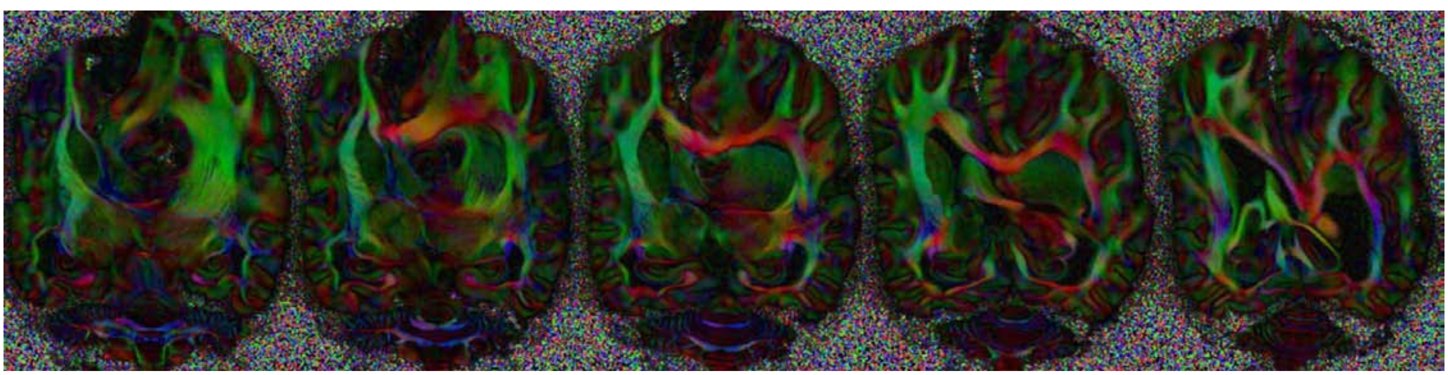

Fig.1 DTI images from a canine brain diagnosed with olfactory neurobalstoma

Conclusion

The current technique provided an accurate and yet quantitative imaging method to map white matter microstructure in fixed canine brain with tumors. Using this procedure, extremely high resolution microstructural images can be obtained. This leads a very accurate method to study microanantomical changes involving with tissue damage and integrity for animal models.

References

1. Holmes AA *et al.* Magn Reson Med 2000;44:157–161.
2. Wedeen VJ, *et al.* Biophys J 2001;80:1024–1028.
3. Guilfoyle DN, *et al.* NMR Biomed 2003;16:77–81.
4. Xue R, *et al*, Magn Reson in Med 1999;42: 1123-1127.
5. Xue R, *et al*, Magn Reson in Med 2001;46: 183-188.
6. Sun SW *et al,* Magn Reson Med, 2005, 53: 1447-1451.