Diffusion Tensor Tractography of Primate Visual Pathway

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Introduction

Diffusion tensor fiber tractography (DTT) reconstructed from diffusion tensor MR imaging (DTI) data set can reveal the anatomical connectivity and/or fiber trajectories of neuronal pathways non-invasively. In particular, the DTT are already widely used in three-dimensional (3D) visualization of main neuronal tracts such as white matter pathways in human brain. It is well known, however, the DTI data set acquired in a complex fiber structure decreases the reliability of the visualization performed by the DTT[1]. Although optic chiasm in well-developed retinogeniculate pathways is a typical situation, the reliability of the fiber trajectories depicted by the DTT remains to be completely verified in visual pathways of non-human and/or human primates. Thus, we performed a validation image analysis of the reliability of the DTT in non-human primate visual pathways possess complex fiber structure at the optic chiasm by using manganese-enhanced MR imaging (MEMRI) tract-tracing[2] analogous to conventional histopathological nerve-tracing methods.

Materials and Methods

Animal preparation: The management of all the animals in this study was approved by the institutional committee on animal experiments. We used 3 healthy common marmosets (females, 290–390 g) and the DTI and MEMRI tract-tracing were performed in these animals respectively. These marmosets were performed tracheal intubation and then administered a mixture of oxygen and isoflurane (concentration, 2.5%) at a constant rate using an artificial respirator. The pulse rate, blood oxygen saturation, and rectal temperature were monitored to maintain them in the physiological range. The right eyeballs of 2 anesthetized marmosets were microscopically punctured by using a 24-gauge needle mounted a microsyringe and the needle was inserted carefully; 0.5 µl of 1M manganese chloride solution ($MnCl_2$) was injected slowly for the MEMRI tract-tracing. The needle was left in the eyeball for 5 minutes to prevent leakage of $MnCl_2$ and was then slowly extracted.

MR Imaging: The DTI and MEMRI were performed by using a 7-T PharmaScan 70/16 system (Bruker Biospin, Ettlingen, Germany) equipped with actively shielded gradients of 300 mT/m maximum strength and a 62 mm-inner diameter transmitting and receiving integrated coil. The anesthetized marmosets were placed on a corresponding acrylic bed and the bed was placed inside a magnet. In vivo DTI data sets were acquired with a diffusion-weighted spin-echo pulse sequence based on a Stejskal-Tanner diffusion preparation. The scanning parameters were as follows: 3500/40 (repetition time msec/ echo time msec), with a motion-probing gradient in 12 non-colinear directions along the (1, 0,±0.5), (0,±0.5, 1), (±0.5, 1, 0), (1,±0.5, 0), (0, 1,±0.5), and (±0.5, 0, 1) axes, b value of 0 sec/mm^2 (for a reference T_2-weighted image (T_2WI) without diffusion weighting) or 1000sec/mm^2, 40 × 40 mm^2 field of view, 128 × 128 matrix, 0.94 mm section thickness, no intersection gap, seven sections, 0.31 × 0.31 × 0.94 mm voxel size, and one signal acquired. The T_1-weighted image (T_1WI) data sets for MEMRI tract tracing were obtained by using a three-dimensional (3D) gradient echo-pulse sequence with flow compensation, before and 24 hours after the administration of $MnC1_2$ into the right eyeball. The scanning parameters were as follows: 40/ 3 (repetition time msec/ echo time msec), 30° flip angle, 60 × 60 mm field of view, 192 × 192 matrix, 96 axial sections, 0.31 × 0.31 × 0.31 mm voxel size, and two signals acquired.

Data analysis and Image processing: A free-delivered diffusion tensor analysis software dTV II SR* and Photoshop Elements 4.0 were used for the DTI data analysis and image processing. To compare the reconstructed DTT images with the retinogeniculate projections delineated by the MEMRI tract-tracing, fusion images were created by using the two modalities. The consistency of the retinogeniculate pathways depicted by the two modalities were mutually collated and visually compared with the morphological findings obtained from previous histopathological studies. *http://www.ut-radiology.umin.jp/people/masutani/dTV.htm

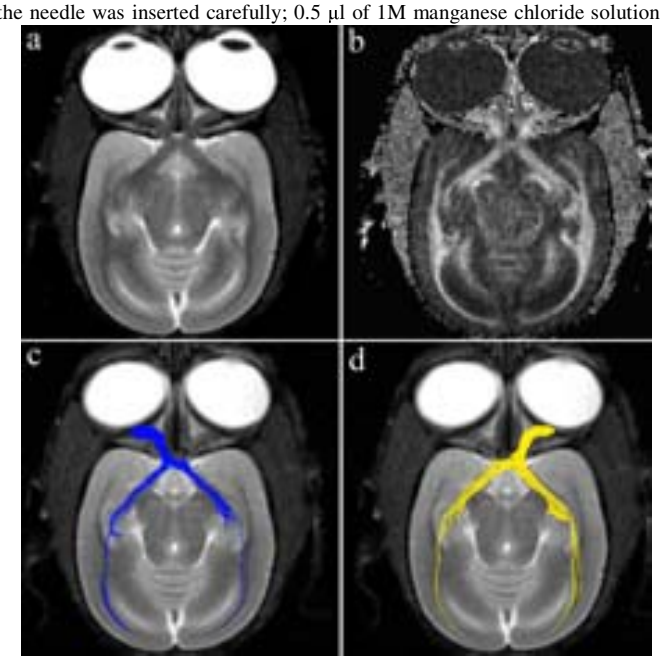

Fig. 1: Representative DTI/DTT images of the marmoset visual pathways. (a) b0 image, (b) FA map, (c) left and (d) right retinofugal pathways.

Results and Discussions

The visual pathways were displayed as conspicuous bright structures because of their high FA value in the FA maps (Fig.1b) and the DTT depicted the typical primate retinofugal pathways branching bilaterally at the optic chiasm (Fig.1c, d). This bilateral retinal projecion was also observed in the MEMRI tract –tracing (Fig. 2). The fusion images superimposing the DTT on the MEMRI tract-tracing showed that the configuration of the retinal projections depicted in two modalities were nearly identical (Fig. 3). Furthermore these findings are supported by those obtained from previous histopathological studies[3].

Conclusion:

We have successfully visualized the non-human primate visual pathways of the common marmosets by using the DTI/DTT and verified its reliability with the assistance of the MEMRI tract-tracing. The findings of our study suggest that the DTT methods play a crucial role in the visualization of well-developed primate visual pathway despite some limitations with regard to the intravoxel fiber crossings. Thus, this potential utility of the DTT will probably be applied for the morphological studies of the visual pathway in human as well as non-human primate.

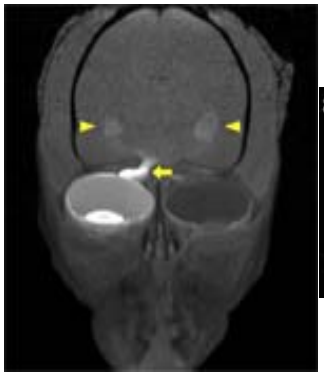

Fig. 2: Representative image of the MEMRI tract-tracing of marmoset visual pathways. Contrast enhancement lead to manganese distribution in the right retinogeniculate projection is clearly visualized: (arrow) right optic nerve, (arrow heads) lateral geniculate nuclei .

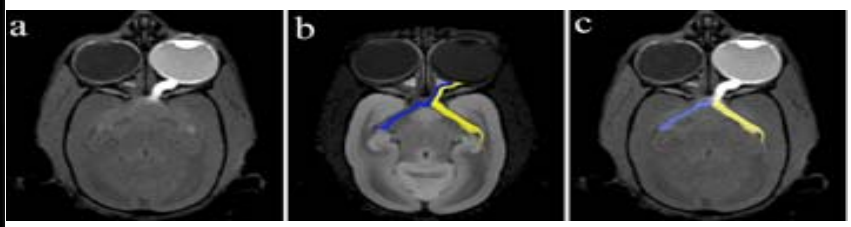

Fig. 3: The configurations of unilateral fiber projection in the visual pathways—(a) MEMRI tract tracing and (b) DTT (ipsilateral projection fibers: yellow lines, contralateral projection fibers: blue lines)—are visualized nearly identical in (c) their fusion image.

Reference:

[1] Mori S, van Zijl PC.: NMR Biomed 2002; 15:468-480., [2] Pautler RG, Silva AC, Koretsky AP. : Magn Reson Med 1998; 40:740-748., [3] Spatz WB.: Exp Brain Res 1978; 33:551-563.