3D DT-MRI atlas of macaque brain

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Introduction

Primate brains, especially macaque brain, have been widely used in neuroscience because of their close relationship with human brains. There are several paper or 2D-based atlases that provide assignments of neural structures. However, these 2D-based atlases are not always suitable for some studies that require 3D registration such as electrode reading and functional mapping. Limited coverage of slice locations and viewing angles is also an issue for precise localization of structures. The purpose of this project is to establish a 3D atlas of gray and white matter structures of the macaque brain in stereotaxic coordinates. High resolution $T_2$ weighted and DTI images were acquired. The data were incorporated into 3D viewer software that allows us to extract 2D slices at desired locations and angles. Gray and white matter structures were segmented and annotated. This stereotaxic atlas is being developed for the purposes of education, anatomical reference, and data registration for various areas of brain research that use macaque brains.

Method

Data acquisition: A 4.7 T Bruker scanner was used. For DTI imaging, 3D multiple spin echo diffusion tensor sequence was used. A set of diffusion weighted images (DWI) was acquired in 7 linearly independent directions. DWI parameters were: TE=32.5ms, TR=0.7s, FOV=80mm/58mm/60mm, imaging matrix=160×80×80 (zero filled to data matrix 256×256×256 with nominal resolution 0.313×0.227×0.234mm$^3$). Gray matter assignment and reconstruction: The major gray matter structures were manually segmented and visualized with software Amira (TGS, San Diego, Calif.). The segmentation was performed using $T_2$-weighted images, DTI colormaps and the macaque brain atlas website [1]. The following major gray matter structures were identified, segmented and reconstructed: ventricle, thalamus, putamen and globus pallidus, caudate, hippocampus and cortex. White matter tract tracing and reconstruction: For the white matter tracing, FACT [2] was used, with a fractional anisotropy threshold of 0.2 and an inner product threshold of 0.75, which prohibited angles larger than 41 degree during tracking. After fiber tracing, the 3D white matter tracts were visualized also by Amira.

Results

Figs 1 and 2 show the annotation of gray and white matter structures in axial and coronal views of DT colormaps and $T_2$ weighted images, respectively. The white matter assignment is based on orientation information in the colormaps and gray matter and gyral assignment is based on the $T_2$-weighted image. In addition to the major white matter bundles, many small tracts can be also clearly identified, for example, ctb and mlf in brain stem in fig 1a. In thealic, the striatopallidal (caudate-putamen) projection can be clearly identified (red streaks in the mostly green alic), which has not been identified clearly in human brain imaging. Fig. 3 gives the snapshots of 3D reconstruction of deep gray matter structures (a) and some white matter tracts (cc and ot). Abbreviations are listed in the figure legend.

Discussion

DT-MRI has been used to set up the human white matter atlas [3]. This study shows the great potential of combined DT-MRI and $T_2$ weighted imaging to establish a stereotaxic brain atlas of the macaque brain. With the DTI resolution about 300μm and $T_2$-weighted image resolution about 200μm, many gray and white matter structures can be identified. The goal of this study is to provide a digital 3D atlas which is expected to be a valuable resource for many macaque-based brain research.