Interactive Digital Stereotaxic White Matter Atlas in Talairach Coordinates (SWAT)

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Introduction: The Talairach atlas [1] is one of the first stereotaxic atlases of human cortex. This Atlas is useful to register information such as the location of activation or lesions, and provides us with a means to compare corresponding regions across different subjects in stereotaxic coordinates. Although the Talairach atlas is widely used, it is primarily designed for cortex registration. Diffusion tensor imaging (DTI), on the other hand, is a relatively new MR modality proving information on various axonal bundles within the white matter. This orientation-based contrast opens up opportunities to establish a white matter registration system and study anatomy–function relationships in white matter. DTI information can be used to generate "addresses" based on anatomic units in otherwise homogeneous-looking white matter. Generation of such addresses is the first step toward the establishment of a white matter functional map similar to cortical functional maps. For this purpose, we here introduce a digital Stereotaxic White matter Atlas in Talairach coordinates (SWAT).

Methods: The DTI dataset is based on Johns Hopkins/Kennedy Krieger DTI white matter atlas [2, 3], acquired on a 1.5 T scanner (2.2 mm isotropic resolution, SENSE=2.5, b=700 s/mm^2, Jones-30 scheme, 6 repetitions). Data were warped to T$_1$-weighted anatomical images using manual landmark-based elastic warping to minimize B0 distortions and then re-sliced to 1 mm^3 isotropic voxel. This atlas is further transformed to Talairach coordinates based on 8-points landmark matching including the anterior/posterior commissure and width/length/height of the brain. There are several ways to use a stereotaxic atlas and custom software are available for each type of usage. First, the atlas can be used to assign white matter structures of interest, such as those affected by diseases. At this level, we need an annotated atlas and a tool that can transform individual data to Talairach coordinate. SWAT has an Image Registration module for the transformation of scalar and tensor data [4, 5]. Once the image of interest is registered, it is straightforward to extract corresponding image slice levels from the subject data and the atlas. If the subject has a lesion in the white matter, this procedure helps us to identify the affected white matter structures. At the second level, this procedure provides stereotaxic coordinates of the lesion location and correlates this with white matter anatomic units. At this level, the heart of the information is the white matter parcellation map (WMPM) that partitions the white matter into the anatomic units. This is a hand-segmented map based on fiber orientation information and classical definition of white matter anatomy. Note that the stereotaxic coordinates such as a Talairach coordinates (a, D, 6) are defined by morphology of the brain, while the WMPM is based on white matter anatomy, which is equivalent to partition of the cortex based on gyral patterns. The viewing software, SWATView, allows us to navigate the atlas and determine the stereotaxic coordinates and the WMPM address. In the third level, we need to register various types of anatomic information such as locations and nature of the lesions to the SWAT. For this purpose, the Information Registration module of SWAT can be used to manually register regions of interest.

Results: WMPM: In Fig. 1, several slices of WMPM are shown. This map parcels the white matter out 26 annotated structures. This hand-segmented white matter atlas is used to relate 3D coordinates to a specific white matter structure. SWATView: A screen shot of the SWATView in Fig. 2 shows three orthogonal views of 2D images and a 3D tri-planar visualization for sliced images and selected fibers with a Talairach coordinate grid overlaying. Absolute or relative millimeter coordinate systems are also available. The user can interactively perform oblique viewing, rotating, zooming in/out, and shifting of the images in real-time. The normalized DTI template along with MRI images, selected fiber-tracts of interest, and WMPM are integrated together in the atlas, providing many features not available in the traditional print brain atlases. The atlas currently works on personal computers with Windows operating system.

Discussion: Although Talairach coordinates are widely used, the original map contains only a limited amount of information about white matter anatomy. In this study, a stereotaxic atlas of the human white matter was introduced. The software can, 1) visualize and study 3D structures of various white matter, 2) transform DTI data into the Talairach coordinate and compare with the JHU/KKI-DTI atlas, 3) identify and record Talairach coordinate of a region of interest and relate white matter structure through WMPM. We believe that this atlas provides a powerful tool for white matter anatomical and functional mapping.
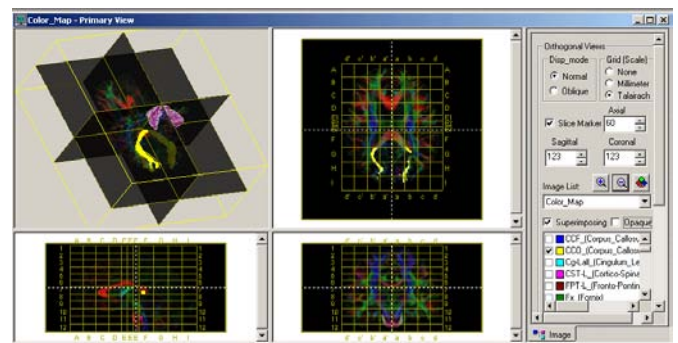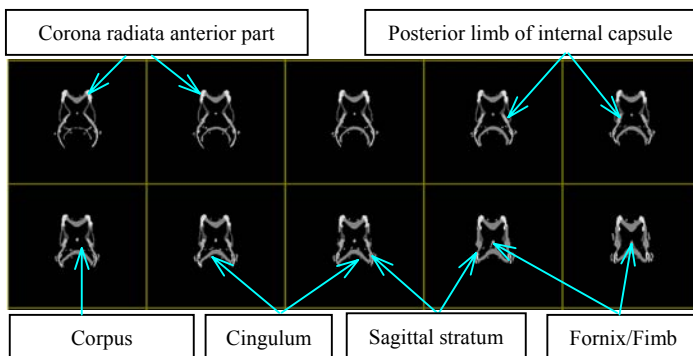

Corona radiata anterior part   Posterior limb of internal capsule

Corpus   Cingulum   Sagittal stratum   Fornix/Fimb

Figure 1: WMPM slices from 50 to 59. Various 3D regions of deep white matter anatomical structures were manually segmented according to fiber orientation information and classical definition of white matter anatomy based on the co-registered MPRAGE, mean DWIs, the color map and FA map.

Figure 2: A screenshot of SWATView. The right part is the control panel, in which contains buttons, radio-checks, drop-down lists, multiple selections and other controls following Windows conventions. The background image, fiber tracts and 3D-anatomical regions of interesting on displaying can be selected from the expandable data list.

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