Atlas-based analysis of human brainstem anatomy as revealed by gradient-echo T2 weighted MR imaging at 7T

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Introduction

Spatial MR image resolution improved drastically with appearance of ultra-high field MR systems. Moreover, new contrasts based on iron concentration in deep nuclei emerged. Iron deposition results in signal drop in T2*-weighted images on high-field systems which helps the segmentation of some mesencephalon structures (e.g. substantia nigra, red nucleus, and subthalamic nucleus) that cannot be well delineated at lower field. This is of a great interest in Parkinson's disease studies where pathological alterations of the aforementioned structures are observed [1, 2]. Nonetheless, for a variant of Parkinson disease some other smaller structures of the brainstem are also involved (e.g. pedunculopontine nucleus PPN) but they cannot be distinguished even with high resolution images at 7T. We have thus analyzed a gradient echo T2-weighted MR acquisition with the help of two different atlases: 1) a 3D histological [3] and deformable [4] atlas, which comprises several nuclei and fiber bundles of the mesencephalon, 2) a printed histological atlas of the entire brainstem [5] that we have numerized and reconstructed for this study.

Material and Methods

Atlas construction – The numerical atlas of the brainstem was built from the atlas of Hausman [5] which consists of drawings of 36 transverse sections of an average sized adult cord and brainstem. The drawings in [5] were made from the photographs of prepared histological sections. We scanned the drawings and labeled the contours providing 130 delineated structures. Then the 36 scanned sections were aligned using landmarks present in the drawings, and the third, axial dimension was reconstructed by interpolating the data between the sections. This results in a 3D atlas of 615x440x278 voxels with an embedded resolution of 84x84x250µm. The 3D histological and deformable atlas was registered with the 7T MR acquisition, providing a tracing of several nuclei and fiber bundles (medial lemniscus, brachium conjonctivum, PPN, red nucleus, substantia nigra, etc). These contours, as well as those provided by the numerized atlas of Hausman, were used as guides by an experienced anatomist to identify the structures directly visible in the MR image.

Acquisitions – axial 2D T_2^* Turbo Spin Echo acquisitions were performed on a Siemens 7T (Siemens, Erlangen) with a 16-channel head coil, setting the following parameters: flip angle FA=15°, T_E=12ms, T_R=550ms, FOV=192mm^2, matrix 512x512, slice thickness=1.95mm, Nex=1.

Results and Discussion

Among the nuclei, the red nucleus, the substantia nigra, inferior and superior collicoli, peri-aqueducal grey, nuclei of the third and fourth cranial nerves, could be delineated in the MR image. Among the fiber bundles, the medial lemniscus, superior cerebellar peduncle, brachium conjonctivum, and cerebral peduncle were delineated.

Thus, several nuclei and fiber bundles could be identified directly in the MR image, while other structures require the resort to anatomical atlases. A 3D histological and deformable atlas of the brainstem will be constructed from these three series of data: the mesencephalic part of the YeB atlas, the 3D version of the Hausman atlas, and the contours directly delineated in the MR image. This new atlas will extent the YeB atlas by comprising both the basal ganglia and brainstem structures, and will benefit from the deformation strategy. This atlas will be used to improve studies of some Parkinsonian syndromes marked by pathological changes in the brainstem, as for instance in the Progressive Supranuclear Palsy [1] and in Parkinson's disease [2].

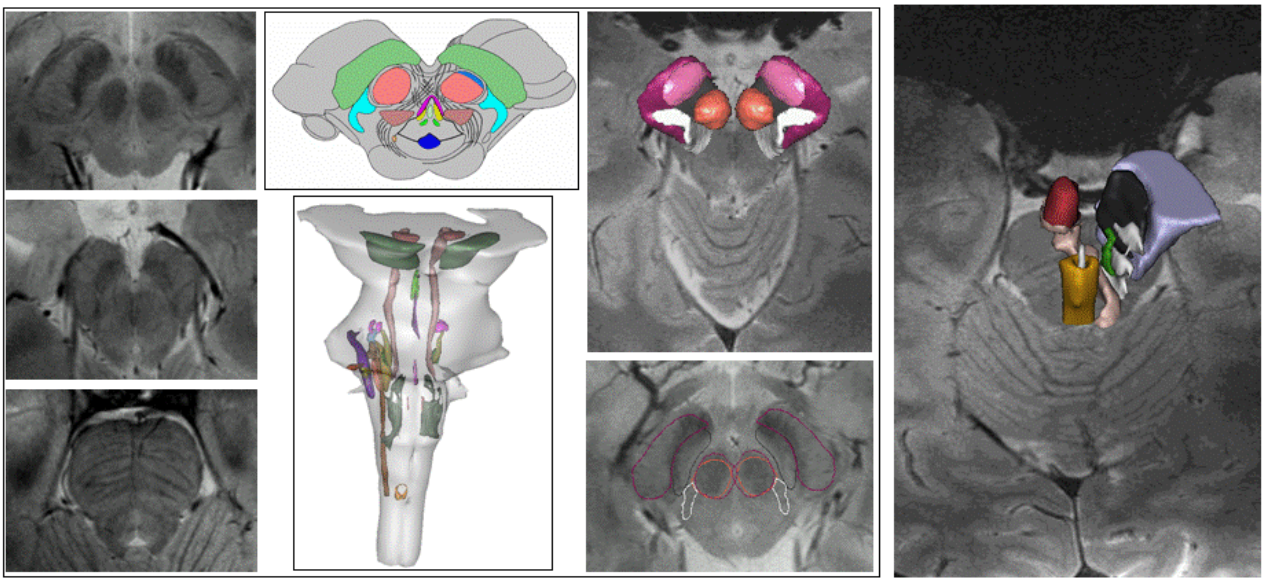

***Figure 1*:** From left to right: 3 axial sections of the 7T MRI; one section of the digitized and labeled histological atlas from [5] and 3D rendering of the brainstem and some of its nuclei; 3D view and one section of the YeB atlas superimposed to an individual anatomy; expert identification of structures in the 7T MRI.

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References

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