Combined DTI fiber tracking and histological 3D atlas mapping of sensorimotor, associative and limbic cortico – striatal circuits

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Introduction. Cortico-striatal connections are organized in segregated circuits, including sensorimotor, associative and limbic circuits (1). In humans, these circuits have been delineated using diffusion tensor based fiber tracking (2) and a 3D histological atlas (3). Delineation of these circuits is important in functional imaging studies. The purpose of this study was to combine these two approaches to build a probabilistic map of cortico – striatal connections.

Material and methods. Eleven right-handed healthy volunteers were studied (age range: 24 ± 2 years). DTI was performed using echo-planar imaging (EPI) at 3T (Siemens) with CP head coil for signal reception. DTI axial slices were obtained using the following parameters (TR/TE/angle: 7.5 s/82 ms/90°, voxel size: 2x2x2 mm^3 no gap, 6 averages). Diffusion weighting was performed along 12 independent directions, with *b*-value of 1000 s/mm^2. A reference image with no diffusion weighting and a 3D anatomical image were also obtained. An atlas of the basal ganglia was constructed from a post-mortem human brain: MRI sequences were acquired, the left hemisphere was further processed for histology; serial contours of the basal ganglia were delineated, including functional (sensori-motor, associative and limbic) territories of the striatopallidal complex revealed by calbindin immunohistochemistry (4); 3D surfaces of basal ganglia structures were built by coregistering atlas data. Automatic registration between atlas and volunteer T1-weighted MR images allowed deformation of atlas surfaces on volunteer's brain hemispheres. Intersection of the deformed atlas surfaces with volunteer's MR slices provided Regions of Interest (ROIs) of the caudate nucleus and putamen functional territories. Fiber tractography was carried out using a geodesic method. Shortest paths with respect to a distance inferred from the diffusion tensor were constructed between each ROI and the cortex for each subject. An accurate anisotropic fast marching algorithm was used for the construction of these geodesics. Then a connectivity index, based on the geodesic distance, was assigned to each path. For each subject, the surface of the cortex has been triangulated and each node of the triangulation was assigned with a connectivity index to each ROI. The triangles were assigned the same color as the ROIs with which they are most highly connected. For multi-subject processing, each individual cortex was warped into the MNI template space using the spm2 software. For each ROI, we counted the percentage of subjects that have a connection with each region of the template cortex.

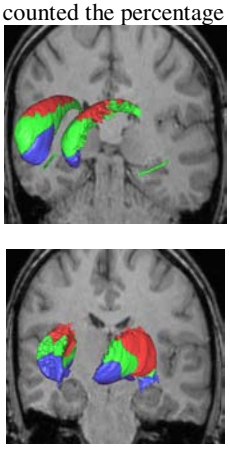

Fig.1 Functional territories of the caudate nucleus and putamen.

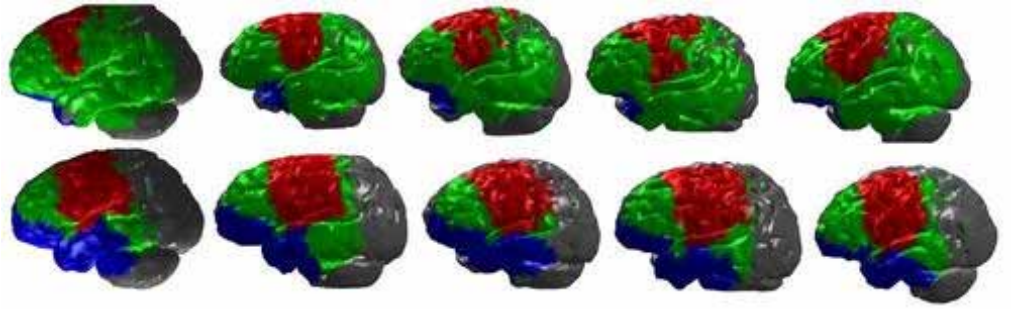

Fig.2 Individual segmentation of the cortex by means of anatomical connectivity index to the caudate nucleus (up) and the putamen (down) functional territories. Five subjects shown.

Results

Fig.1 shows the sensorimotor (red), associative (green) and limbic (blue) territories of the caudate nucleus (up) and the putamen (down) as delineated by the deformed atlas on a volunteer's brain.

Individual (Fig.2) and group analysis (Fig.3) show a high correspondence between the DTI connectivity maps and the expected connections of the sensorimotor, associative and limbic territories. The 'sensorimotor' territory of both the caudate nucleus and the putamen was connected with the sensorimotor cortex as well as premotor areas. Connections with associative cortical areas were predominant in the caudate nucleus. The orbitofrontal cortex, temporal poles and medial temporal areas were connected with the 'limbic' compartment.

Fig.2 shows interindividual variability of the connections of each functional territory.

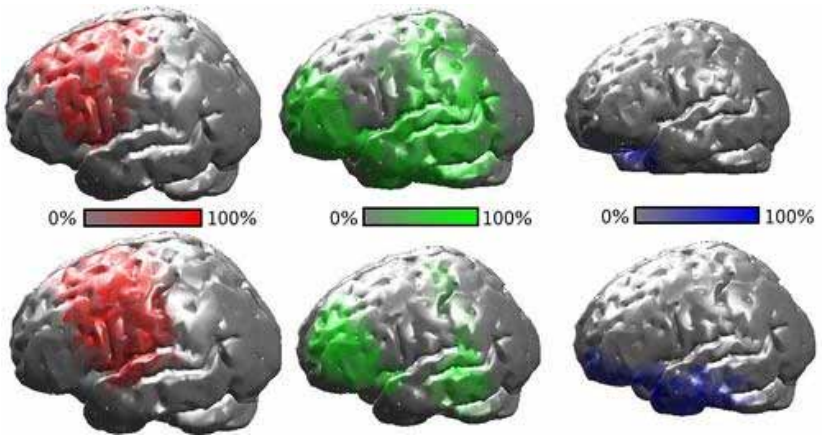

Fig.3 Group connectivity map to the caudate nucleus (up) and the putamen (down) functional territories.

Conclusion. These results provide a 3D atlas and connectivity-based segmentation of the striatum. They also show a high agreement between 3D atlas based segmentation of the striatum and DTI fiber tracking results.

References. (1) Alexander et al. Annu Rev Neurosci 1986, (2) Lehéricy et al. Ann Neurol 2004, (3) Lehéricy et al. Cereb Cortex 2005, (4) Karachi et al. J Comp Neurol 2002.

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