Three dimensional probabilistic atlas of the human striatal territories based on diffusion imaging

M. Thiebaut de Schotten[1], M. Herrero Ezquerro[2], E. Bardinet[3], C. Poupon[4], H. Benali[5], J. Yelnik[6], and S. Lehericy[7]

[1]INSERM U610, University Pierre and Marie Curie - Paris 6, Paris, France, [2]Department of Human Anatomy & Psychobiology, University of Murcia, Murcia, -, Spain, [3]CNRS UPR 640, University Pierre and Marie Curie - Paris 6, Paris, France, [4]Neurospin, CEA - DSV, Saint Aubin, France, [5]INSERM U678, University Pierre and Marie Curie - Paris 6, Paris, France, [6]INSERM U679, University Pierre and Marie Curie - Paris 6, Paris, France, [7]INSERM U610 - Department of neuroradiology, University Pierre and Marie Curie - Paris 6, Paris, France

Introduction. The basal ganglia are organized in distinct territories that are connected to distinct cortical areas, including the motor, premotor, prefrontal, and orbitofrontal cortex (1). As a consequence, the basal ganglia are involved not only in motor control, but also in several different types of cognitive and limbic functions as well. In humans, diffusion imaging and fiber tracking can be used to localize these territories in the striatum (2). Delineation of these circuits has important implications for understanding the anatomical and functional organization of the basal ganglia. The purpose of this study was to build a 3D probabilistic atlas of striatal territories based on cortico – striatal diffusion fiber tracking.

Material and methods. Thirteen healthy right-handed volunteers were studied at 1.5T. Diffusion parameters were TR/TE/angle: 19s/93ms/90°, voxel size: 1.88x1.88x2 mm^3, b-value: 3000 s/mm^2, 200 directions and 1 B0 image. Diffusion image analysis was performed using Q-ball imaging and probabilistic fiber tracking algorithm using Brainvisa 3.0.2 (http://brainvisa.info). Fiber tracking was performed between the striatum (putamen, caudate nucleus and nucleus accumbens) and the cortical regions. ROIs were manually traced using Brainvisa 3.0.2. The cerebral cortex was segmented in several areas including the primary motor and sensory areas, the premotor, dorsal and ventral lateral prefrontal cortex, medial and lateral orbitofrontal cortex, supplementary motor area (SMA), preSMA, cingulate cortex, insula, inferior and posterior parietal, temporal and occipital cortex. EPI B0 images were normalized to the MNI space by using SPM2 software and the resulting deformation matrix was applied to the fiber bundles. Fiber tracks included all MNI template voxels crossed by this normalized bundles. Bundles of all subjects were overlapped to create a map that was thresholded for each voxel using the percentage of subjects having a fiber crossing the voxel as a threshold. The putamen was segmented using the termination endpoints of each cortico-striatal bundle. Results are presented for the putamen.

Results. There was a topographic organization of striatal territories (Figure 1). Primary sensorimotor and SMA territories largely overlapped and were located in the dorsal and posterior part of the putamen. preSMA territory was located rostral to the SMA territory. The dorsolateral prefrontal territory was located in the anterodorsal part of the putamen and the limbic territory in the ventral area.

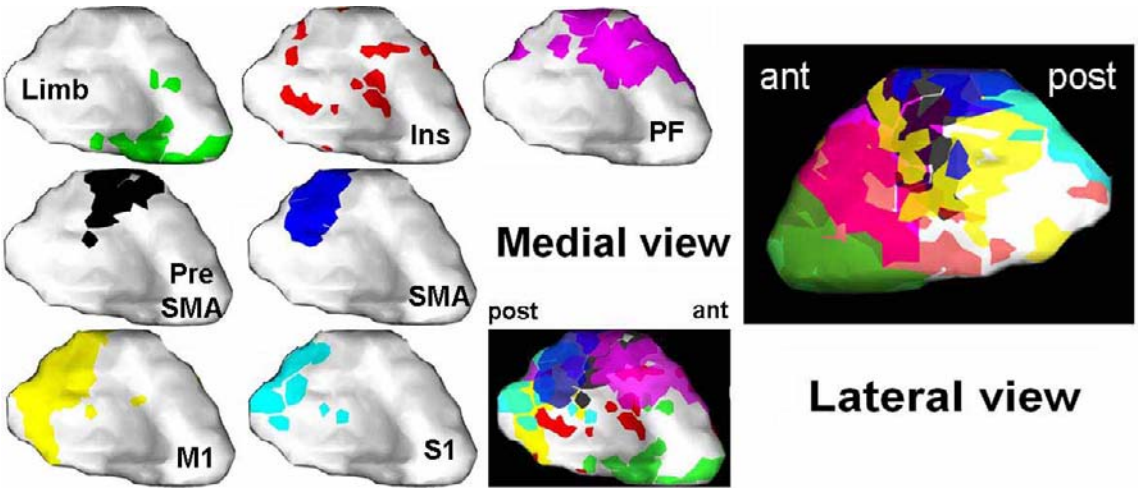

Figure 1. Three dimensional reconstructions of the putamen showing the territories of the orbitofrontal cortex (limb) in green, the insula (ins) in red, the dorsolateral prefrontal cortex (PF) in purple, the preSMA in black, the SMA in dark blue, the primary motor cortex (M1) in yellow, and primary sensory cortex (S1) in light blue. Three columns on the left: medial views, right: lateral view. The two images in a dark background are the combined maps of all territories. The other territories are not shown (parietal, temporal).

Conclusion. These results provide a 3D atlas of the striatum in the MNI space based on diffusion fiber tracking. This atlas can be used to locate fMRI activation, lesions and to look for abnormalities of diffusion variables in each territory in neurological pathologies. Results are in agreement with expected locations of striatal territories based on axonal tracing studies in animals and 3D deformable histological atlas in humans (3).

References. (1) Alexander et al. Annu Rev Neurosci 1986, (2) Lehericy et al. Ann Neurol 2004, (3) Yelnik et al. NeuroImage, in press.

Acknowledgments. This study was supported by grants from the IFR49.