# Somatotopic organization of hand- feet- lips- and tongue-related fibres identified by fMRI and DTI in controls and patients with brain tumours

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**Introduction.** The exact anatomical relationship of the motor tracts for hands, feet, lips and tongue has been described but remains controversial (1). However, this knowledge would have important clinical applications, especially in the preoperative localization of the corticospinal tract (CST) in patients with brain tumours displacing or infiltrating the fibres. Recent diffusion tensor imaging (DTI) studies mainly investigating just the hands- and feet-related fibres, suggest a somatotopic organization reflecting the homunculus organization of the motor cortex. The aim of this study was to investigate the somatotopic organization of the motor tracts by using a combination of 2-tensor model probabilistic DTI tractography and functional MRI (fMRI) to identify the cortical areas in the precentral gyrus responsible for hands, feet, lips and tongue movement.

**Methods.** fMRI and DTI data were acquired on a 1.5T GE MRI system from 5 controls (median age 30 (range 25-41) years; 3 men) and 9 tumour patients (median age 37 (range 18-61) years; 8 men). The tumours were located in proximity to the left (in 8 patients) or right (1 patient) motor tracts. Protocol. an anatomical 3D-T1 image with inversion time 450ms, 1.2x1.2x1.2mm$^3$ resolution; 3 DTI acquisitions with TE/TR=91.5/10000ms, 25 gradient directions, b-value=1000 s/mm$^2$, 3 b=0 images, 2x2x3mm$^3$ resolution, 33 contiguous axial slices; 6 fMRI data sets (R hand, L hand, R foot, L foot, lips, tongue) with gradient-echo echo-planar sequence, TE/TR=50/4000 ms, 3x3x3mm$^3$ resolution, 39 contiguous axial slices, 5.5 min per run. fMRI paradigm: "block" design alternating periods (of duration 20.25s) of rest and of self-paced motor task (hands: finger-thumb opposition, feet: toe flection/extension, lips: pucker-up, tongue: random movement of tongue inside the closed mouth). Data processing: DTI data were analysed with FSL (www.fmrib.ox.ac.uk/fsl/), probabilistic tractography, 2-tensor model, 10000 samples. fMRI data were analysed with SPM5 (www.fil.ion.ucl.ac.uk/spm/). The SPM{t} maps, corrected for multiple comparison, were thresholded at levels optimized for each subject in order that the highest intensity peak in the pre-central gyrus could be selected and used as a seed region for the tractography. The cerebral peduncles were used as waypoints. An exclusion mask was positioned in the midline of the brainstem.

**Results and Discussion**

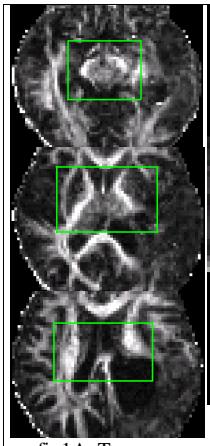

fig1A. Tumour patient fractional anisotropy map. Green regions enlarged in fig1b.

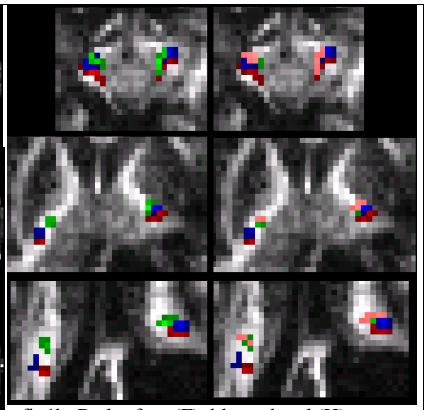

fig1b. Red = foot (F), blue = hand (H), green = lips (L), pink = tongue (T); top = cerebral peduncle, middle = internal capsule, bottom = cella media. Left image shows: F, H, L. Right image shows: F, H, L, T

Overall, hand (H) motor tracts were identified in 100% of patients and 80% of controls; feet (F) tracts in 89% of patients and 60% of controls; lips (L) and tongue (T) tracts in 78% of patients and 60% of controls.

All 4 motor tracts were identified in 5 patients and 2 controls. In these subjects the fibres were located in the mid third of the cerebral peduncle (CP), posterior limb of the internal capsule (PLIC), and in the cella media (CM). At all levels there was a certain degree of overlap between the tracts, but it was possible to identify a lateral to medial somatotopic organisation in the CP, posterior to anterior along the PLIC and in the CM. An example is shown in fig1b. In the CP, F was always lateral, followed by H/L/T (all three overlapping) in 60% of the patients, or by H and then L/T in 40% of the patients. In the PLIC, F was always posterior, followed in equal proportions by either H and L/T or H/L and T. In the right (non-lesional) hemisphere of one patient only the F was followed by L/T and then by H. In the CM, F was always postero-medial, while H was antero-lateral to F and L/T antero-medial to H in 80% (60%) of patients in the right (left) hemisphere. In one patient only, in the CM on the lesional hemisphere, the F was followed by L/T and then by H.

The presence of a lesion predominantly caused displacement of the tracts without affecting their relative organisation (in 63% of patients). In the remaining 4 patients and 3 controls 2 or 3 motor tract components were identified. Their relative organisation is consistent with the finding in the 5 subjects in which all 4 components could be identified. The results in controls were consistent with those in patients.

**Conclusions.** The combined DTI/fMRI method used enabled the identification not only of the motor hands and feet components of the corticospinal tract, but also the motor tracts for lips and tongue. Our results confirm a somatotopic organization of the foot and hand tracts and in addition describe the organization of lips and tongue in the CP, posterior half of the PLIC and CM. The lips and tongue tracts were located in the anterior portion of the PLIC and CM and medial portion of the CP. The feet tracts were located in the posterior aspect of the PLIC and CM and in the lateral aspect of the CP. The presence of a tumour predominantly caused displacement of the tracts without affecting their relative anatomical organization. These results are relevant for presurgical assessment of patients with brain tumours.

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**References.** [1] AI Holodny et al. Radiology 2005; 234:649-653.