Topographic organization of SMA connections as assessed by MR DTI tractography and intraoperative subcortical mapping

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Introduction

Supplementary motor area (SMA) is a crucial cerebral region involved in the temporal organization of motor tasks, especially in sequential performance of multiple movements. SMA is located in the medial part of the superior frontal gyrus (BA6) [1]. In humans, SMA includes two separate subregions: an anterior part, the pre-SMA, and a posterior part, the SMA proper [2]. Electrophysiology studies in non human primates have shown that the homologous area of SMA proper has a representation of movements somatotopically organized [3]; moreover, a rostra-caudal somatotopic distribution of subcortical connections of this area has been demonstrated in the macaque monkey by injecting neuronal tracers [4]. In humans, fMRI studies identified distinct foot, face and hand representations in SMA, suggesting the existence of a topographic cortical organization, as well [5]. Few data are available on the subcortical organization of this region [6]. Intraoperative subcortical stimulation is a powerful technique allowing at the time of surgery to identify subcortical tracts located either around or within a lesion, and to preserve them. At the same time, by combining subcortical mapping with tractography data, integrated information onto functional connections of a certain area of the brain can be obtained in order to design its subcortical connectivity [7].

Purpose of this study was to explore functional connections of SMA proper by the means of intraoperative subcortical mapping and DTI tractography in patients with cerebral gliomas; data from stimulation were retrospectively used to define anatomical regions of interest for tractography-based segmentation of subcortical connections of SMA.

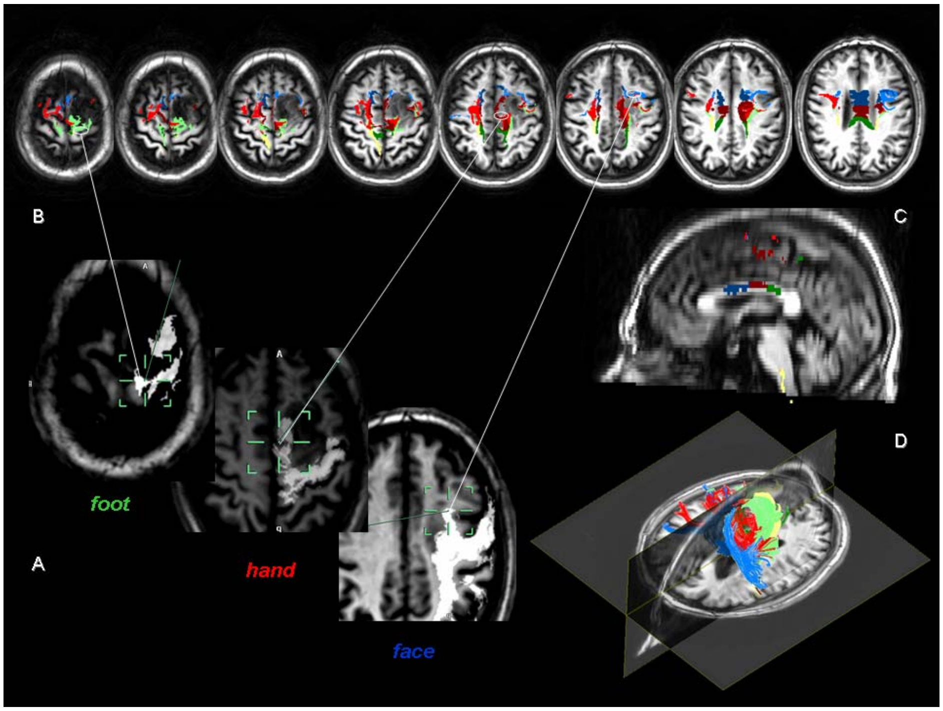
Material and Methods

19 patients with gliomas (14 LGG, 5 HGG) located in SMA were studied on a 3T scanner (Philips Intera, Best, The Netherlands) with a 8-channel head coil. MR DTI data were collected using a single-shot echo planar imaging (EPI) sequence (TR/TE 8986/80 ms) with parallel imaging (SENSE factor, R = 2.5). 32 diffusion gradient directions (b=1000 s/mm^2) and one image set without diffusion-weighting were obtained. Acquisition coverage extended from medulla oblongata to the brain vertex (56 slices, no gap), with isotropic voxel dimensions (2.5 × 2.5 × 2.5 mm^3). The sequence was repeated two consecutive times and data were averaged off-line to increase signal-to-noise ratio; DTI datasets were aligned off-line to the echo-planar volume without diffusion weighting on a PC workstation using the AIR (Automatic Image Registration) software to correct artifacts due to rigid body movement during scan acquisition. T1-weighted structural imaging (3D Fast Field Echo, TR/TE: 8/4 ms; image resolution equal to DTI) was performed for anatomic guidance. In all patients preoperative tractography from motor and supplementary motor area was performed based on a streamline algorithm using Dti Studio version 2.4.01 software (Jiang H, Mori S, Radiology Department, Johns Hopkins University, Baltimore, MD, USA). Data were transferred to the neuronavigation system as described in [7].

All patients had awake surgery with the aid of subcortical mapping [7]; the type, number and location of each subcortical response was registered into the neuronavigational system. DTI data were retrospectively processed by placing starting ROI in correspondence of the sites in which positive motor responses were evoked, to segment by tractography the position and course of subcortical connections of SMA.

Results

During intraoperative subcortical mapping motor responses, mainly contralateral, but also ipsi or bilateral, were obtained in all patients. Motor responses showed an anterior to posterior somatotopic distribution (from eye to leg); ipsilateral motor responses were located more laterally to the fibers inducing contralateral responses. Correlation with DTI tractography post-processing data showed that SMA contributed to CST, was connected with ipsilateral primary motor area (M1), premotor area and contralateral SMA, but not controlateral M1. Connections depicted by tractography had a similar anterior to posterior distribution, as showed in Fig.1.



Discussion and Conclusions

SMA has a complex network of connections with both ipsi and contralateral brain regions. Understanding of this network is critical to guide surgical removal of gliomas located in this area and to predict the onset of postoperative deficits. In this study we used data from intraoperative subcortical mapping to define starting ROI for tracking connections from SMA in patients with gliomas; tractography findings confirmed functional stimulation data, by depicting an anterior to posterior distribution of SMA connections, from face to leg. Further developments will probably come from a probabilistic approach [8], as we are using the locations of subcortical response as seeding regions during probabilistic diffusion tensor tractography to segment the position and course of subcortical connections of SMA, in order to confirm ulteriorly the functional and anatomical organization showed in the present study.

◄*Fig.1. Tractography segmentation of SMA in a patient arboring a left frontal oligodendroglioma. A, images from the neuronavigational system showing the sites of motor responses for face, hand and foot and corresponding ROIs for tractography (white circles). B, axial sections with tractography representation of subcortical connections (face corresponding connections in blue, hand in red, foot in green) with an anterior to posterior distribution. Yellow, corticospinal tracts. C, Dark colours = controlateral fibers, as showing in midsagittal section. D, 3D representation.*

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