

Anatomic vs. Functional MRI Seeding of the Corticospinal Tract in Patients with Brain Tumors

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Introduction

In order to improve the surgical treatment of patients with brain tumors, it is important to identify eloquent cortical areas and the associated white matter tracts. Injury to these eloquent areas during surgery may lead to devastating motor and/or language deficits. Functional MRI (fMRI) can accurately identify the primary motor cortex in the preoperative setting, as confirmed by direct cortical stimulation in the operating suite (1). Diffusion tensor imaging (DTI) allows the in vivo visualization of white matter tracts (2-4). Integrated fMRI and DTI can offer valuable anatomic and functional information about eloquent grey matter and white matter fiber tracts, respectively. Rather than relying on anatomic references, the fMRI activated voxels may be used as seed regions-of-interest (ROIs) to generate tractography of the white matter tracts. We hypothesize that fMRI driven tractography can more accurately predict the location of the hand associated fibers of the corticospinal tract than anatomy driven tractography in patients with brain tumors near the motor cortex.

Subjects and Functional Tasks

12 right-handed patients with 10 primary and 2 metastatic brain tumors located <1 cm from the motor cortex were imaged on a 3T GE magnet. fMRI was performed with a block paradigm using hand finger tapping (20 sec active, 30 sec rest) administered at a 1 Hz pace. Functional images were acquired with TR/TE=4000/40 ms; 128x128 matrix; 4.5 mm thickness. Functional activity was generated using cross correlation analysis with activated pixel threshold of $p < 0.0001$. DTI was acquired using a single shot diffusion weighted spin echo echo planar sequence in 25 noncollinear directions, TR/TE=11000/64ms, 128x128 matrix; 3 mm thickness, 1000 s/mm² maximal b value. fMRI and DTI analysis was performed using AFNI and DTI Studio, respectively (5, 6). For tracking the hand associated fibers of the corticospinal tract, a neuroradiologist (CAQ, 5 years of experience with fMRI/DTI) placed anatomic ROIs in the hand homunculus on the tumor and nontumor sides and an MRI physicist (12 years of experience) independently placed functional ROIs using the fMRI activated voxels. Differences between the anatomic and functional methods and between sides were evaluated using paired t-tests with $p < 0.05$.

Results

Careful visual inspection showed the generated fibers to be appropriately located in all cases, while blinded to the anatomic vs. functional method used. A representative case is shown in Fig 1. The median fiber counts of the corticospinal tract for the anatomic method (589 tumor, 381 nontumor) were less than the counts for the functional method (615 tumor, 665 nontumor), but this did not reach statistical significance ($p > 0.29$). The maximal fiber lengths between the anatomic method (116 tumor, 104 nontumor) and the functional methods (96 tumor, 110 nontumor) were not statistically significant ($p > 0.06$). The differences between the two methods on the tumor and nontumor sides were also not statistically significant ($p > 0.34$).

Fig 1. 59 year old patient with a glioblastoma in the posterior left frontal lobe located <1 cm from the precentral gyrus. (A) Axial color FA map with superimposed bilateral fMRI motor activated voxels (red areas) and left frontal tumor (outlined in white); (C) coronal corticospinal tracts generated from fMRI seeds. (B) Axial color FA map used for anatomic seeding and reconstructed (D) coronal corticospinal tracts.

Discussion

fMRI driven tracking is expected to be more accurate than anatomy driven tracking, particularly in patients with distortion of normal anatomy by adjacent brain tumors. Similar results were found for the corticospinal tract, however, between anatomy driven seed ROIs and fMRI driven seed ROIs of the motor cortex. Anatomy driven fiber tracking may be as accurate as fMRI driven fiber tracking when performed by an experienced operator, even in patients with brain tumors. Correlation of these techniques with direct cortical and subcortical stimulation during surgery is necessary for further validation of the generated fiber tracts.

References

1) Petrella 2006. 2) Golay 2002. 3) Mori 2002. 4) Field 2004. 5) Jiang 2006. 6) Cox 1996.

