

Combining functional MRI and Diffusion Tensor Imaging in the pre-operative assessment of the hand and foot fibers within the corticospinal tract

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Background

Functional MRI (fMRI) has gained an important role in identifying the location of the hand and foot primary motor areas pre-operatively. Less attention, however, has been given to the course of the major white matter tracts, such as the corticospinal tract (CST). Inadvertent transection of the CST during neurosurgery may have devastating results for the patient.¹ The location of the CST in humans is variable and the tract may be displaced by a cerebral tumor.² Diffusion tensor imaging (DTI) is used to depict the course of these tracts. Fiber tracking purely based on the supposed anatomical localization of the CST, such as in the cerebral peduncle, is not sufficient to specifically depict the most important fibers, i.e. of the hand and foot, of the CST. Our goal was to make a better pre-operative assessment of these CST fibers. We performed a feasibility study in which we show that a combination of fMRI and DTI within a clinically applicable protocol may be used to evaluate the spatial relationship between the CST hand and foot fibers and tumor borders using the functional location of the primary motor area (PMA) as established with fMRI.

Material and methods

Five patients (age range 31-56 yrs) with cerebral brain tumors were referred for pre-operative assessment of the PMA and the CST of the hand and/or foot. All patients had a primary intra-axial brain tumor located in the vicinity of the PMA. Imaging was performed on a 1.5T scanner (Signa CV/I, General Electric, Milwaukee, US). For functional imaging, a T2* weighted gradient echo EPI sequence was used (TR/TE 3000/40 ms; matrix 64x96; voxel size 3.3x2.2x3.2 mm³). Acquisition time was 5:15 mins. The stimulation paradigm consisted of a blocked design of either finger or foot tapping versus rest (30 s/block; 10 blocks). For anatomical reference a high resolution 3D FSPGR IR T1 weighted sequence was used (TR/TE/TI 9.9/2.0/400 ms; ASSET factor 2; matrix 320x224; voxel size 0.75x1.1x1.6 mm³). Acquisition time was 3:10 mins. The DTI sequence was a single shot spin echo EPI sequence (TR/TE 8000/68.7; ASSET factor 2; matrix 64x96; reconstructed voxel size 1.6x1.6x3.5 mm³). Maximum *b* value was 1000 mm²s⁻¹ in 25 noncolinear directions. Acquisition time was 3:44 mins.

Functional and anatomical images were coregistered with the DTI images using Statistical Parametric Mapping version 2 (SPM2; Wellcome dept. University College London, UK). Functional data were smoothed with a 3D Gaussian filter of 6x6x6; no normalization was performed. Individual statistical parametric maps were calculated using the general linear model analysis as implemented in SPM2, and thresholded at T>5. Fiber tracking was performed with the free software dTV for MR-DTI analysis (University of Tokyo Hospital, Tokyo, Japan) using the continuous tracking method (FACT).³ Tracking was initiated from a manually selected seed region of interest (ROI) that was chosen in the white matter area adjacent to the maximum fMRI activity. One target ROI was placed on the cerebral peduncle, on the basis of anatomical knowledge of the fiber projections. Tracking was terminated when it reached a pixel with a certain FA value. This FA threshold was varied per patient (range 0.12-0.20) to determine the optimum threshold for an individual tract.

Results

In all five patients, we were able to track the hand fibers of the CST on both sides. In two patients who performed foot-tapping, we could make a clear distinction in hand and foot fibers by fiber tracking. In three patients, the PMA was displaced by the tumor. The tracked CST in these patients was also displaced compared to the other side (fig. a,c). In two of these patients, the CST ran through nonenhancing areas of decreased signal intensity on the T1 images (edema or tumor infiltration; fig. b). These tracks could only be visualized using an FA threshold of 0.12. Using more conventional higher thresholds, the tracts disappeared. In one patient both PMA and CST showed a close relationship with the tumor border, but were not displaced. In one patient, the PMA of the hand was at a considerable distance from the tumor. DTI in this patient, however, showed that the hand fibers ran adjacent to the tumor border.

Conclusion

Combining fMRI and DTI in the pre-operative assessment of brain tumor patients can provide essential information not only on the location of functional cortical areas, but also on the course of important white matter tracts. We found that tracking of the CST from the fMRI activation area can show the (deviated) course of the tract and its relationship to the tumor. Fiber tracking in tumor areas needs to be customized, since too high FA termination thresholds may lead to failure of fiber tracking in case of tumor infiltration or edema.

References

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2. Holodny AI, Gor DM, Watts R, Gutin PH, Uluğ AM. *Radiology* 2005; **234**:649-653.
3. Mori S, van Zijl PC. *NMR Biomed* 2002; **15**:486-480. Software available at <http://www.utradiology.umin.jp/people/masutani/dTV.htm>

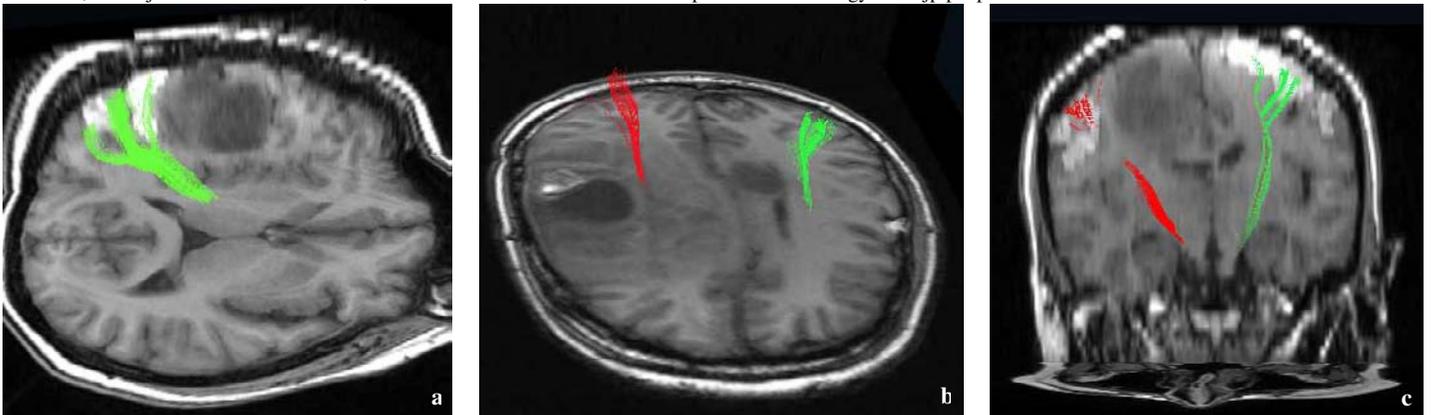


Fig. a,b,c: Hand fibers in the CST on the left (green) and right side (red), projected on anatomical images in two orthogonal planes (fig. a,c); hand PMA as established with fMRI is shown as white overlay (fig. a,c).