Comparison of Fiber Tracking Techniques in Combination with Functional Localization in Brain Tumor Patients

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Introduction: DTI fiber tracking can be used in combination with functional localization to delineate specific subcortical pathways. Magnetic source imaging (MSI) is a non-invasive technique of localizing sensory cortex based on the magnetic fields produced by active neurons. Intraoperative stimulation of the exposed cortex provides precise functional localization in motor cortex. MSI and cortical stimulation are routinely performed to aid in the planning of tumor resections. Knowledge of the location of motor and sensory subcortical pathways in relation to a tumor's borders improves the surgeon's ability to avoid operative morbidity. This study uses both streamline and probabilistic fiber tracking techniques to evaluate their utility in combination with functional localization in tumor patients.

Methods: *MR Scanning:* MR scans were performed at 1.5T with a single-shot multirepetition echoplanar sequence and TR/TE = 10000/100ms, slice thickness between 2 and 2.3 mm, no gap, voxel volume between 4.5 and 9 mm^3, and 4 to 6 NEX. Diffusion gradients were applied in 6 non-colinear directions with b= 1000 s/mm^2 in addition to a b=0 s/mm^2 image.

Functional Localization: MSI mapping of somatosensory cortex was performed using dual 37-channel biomagnetometers (4-D Neuroimaging Inc.). Somatosensory stimuli were pneumatic-driven pulses delivered to different skin sites. A single dipole was fitted at each time-point of the evoked magnetic field response. Dipole parameters at the peak SNR in the response that passed correlation (>0.96) and goodness-of-fit (>0.96) criteria were then chosen for MR overlays. Cortical stimulation was performed during craniotomy surgeries with a bipolar stimulator probe touched to exposed cortical sites under stereotactic guidance. The localized motor and sensory cortical points were then used for launching DTI tracks.

Fiber tracking: Fiber tracks were constructed using software based on the FACT[1] streamline algorithm, which follows the primary eigenvector in 3D continuous space. The fast marching probabilistic method was also used. Fast marching is a probabilistic method of determining brain connectivity by evolving a front from a starting point [2]. The speed of the front is determined by the coherence of the primary eigenvectors. The top 10% of tracks created by fast marching with a modified probabilistic metric and restricted front evolution were used for analysis in this study. Both fiber tracking techniques were launched from each of the cortical sites. The successes of sensory and motor fiber tracks were judged by their ability to show connectivity through the internal capsule to the level of the thalamus and midbrain, respectively.

Results: A total of 48 somatosensory cortical sites were identified on 7 patients with MSI and corresponded to 35 finger, 4 toe, and 9 lip sensations. The probabilistic method showed connectivity from finger MSI sites through the internal capsule in 65% of cases while the streamline method was successful in 17% of cases. A total of 19 primary motor cortex sites were identified on 6 patients through cortical stimulation. The probabilistic method was successful and performed better than the streamline technique from 3 upper extremity motor sites and 2 mouth motor sites. The streamline method was successful and performed better than the probabilistic method in 4 finger or hand motor sites. Both tracking techniques were successful from 8 motor sites.

Discussion/Conclusion: Both fiber tracking methods used in this study are guided by the primary eigenvector of the

diffusion tensor model, but the probabilistic method can more readily transverse bifurcations and fiber crossings. However, the probabilistic method was observed to have lower specificity and present more false positives. These results further emphasize the necessity of filtering DTI fiber tracks with independent functional localization for both improved confidence and validation. The superior longitudinal fasciculus (SLF) was observed to impact both the probabilistic and streamline trajectories originating from upper extremity motor and sensory cortices. The probabilistic method has the ability to cross the SLF and enter the internal capsule as demonstrated by higher success rates from finger MSI sites. Fiber tracking can determine which margins of tumors are closest to the pyramidal tract and somatosensory radiation. This information is crucial for surgical planning and guidance of time-consuming subcortical stimulations performed during resection to identify pathways to spare.
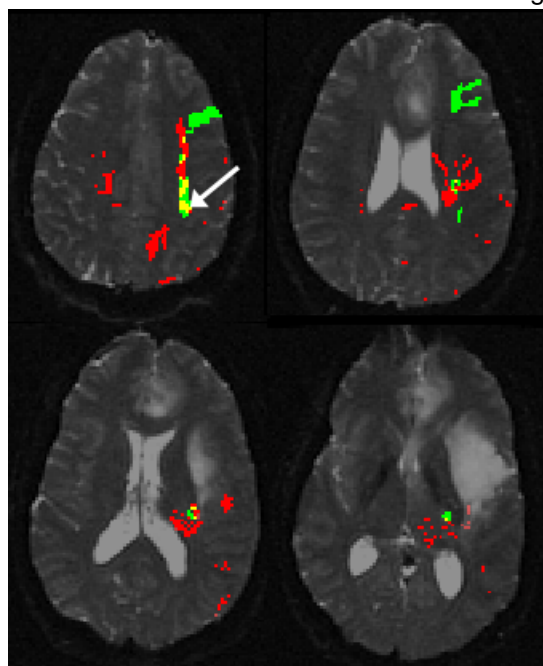
Figure: Shows an example of probabilistic (red) and streamline (green) fiber tracks from a right lip MSI site on the somatosensory cortex (arrow). The top 10% of probabilistic tracks are shown and all streamline tracks are shown. Overlapping voxels are yellow. In addition to pathways down the internal capsule, each technique shows connectivity to the frontal lobe.

References
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2) Parker GJM. et al. IEEE Trans Med Imaging. 21:5, May 2002.