Diffusion tractography of the motor pathway in high grade brain tumor patients: A comparison of constrained spherical deconvolution (CSD) and DTI algorithms

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Introduction: The complete and safe resection of infiltrative high grade brain tumors is extremely difficult as they are often located near and displace eloquent regions of the motor cortex and white matter. An obvious application of DTI tractography is to visualise for the neurosurgeon those white matter tracts that connect the eloquent cortex to the corticospinal tract. To perform such tractography on individual patients is not trivial as it requires tracking through complex white matter anatomy (involving bending and crossing fibres) that in some areas may have reduced anisotropy from edema and tumor infiltration. In addition, seeding from known anatomical landmarks of eloquent cortex is not possible due to displacement of these areas by the mass affecting tumors.
The aim of this study was to investigate whether a probabilistic tractography algorithm [1] based on CSD (SDPROB) [2] was superior for visualisation of the motor pathway in patients with high grade brain tumors. The hypothesis is that diffusion MRI tractography algorithms that are not limited to a simplistic DTI ellipsoidal model would allow for more accurate representation of the motor pathways in the brain than traditional DTI and deterministic stream tracking algorithms. Given that fMRI identified eloquent cortex must be connected to the corticospinal tract via the motor pathway. We used the volume (%) of tracts intersecting with independently determined fMRI eloquent motor cortex (TVI) as a quantitative method for determining algorithm performance. TVI from SDPROB tractography was compared to traditional stream tracking algorithms based on CSD (SDST) and DTI eigenvectors (DTST).

Materials and Methods:

Subjects and Image Acquisition: Data were acquired from two patients admitted for salvage surgery of a recurrent glioblastoma multiforme on a 3T Siemens Trio (8 Channel phased array coil). Data acquisition included a pre and post contrast agent isotropic FSPGR T1 weighted scan , 3 FMRI time series (4 x rest and stimulus periods consisting of 10 repetitions, TR/TE = 3000/30, slice thickness = 3) during stimulation of the face, hand and foot motor cortex, and a 30 direction double refocused DWI series (2.5 x 2.5 x2.5 mm resolution, TR/TE = 3000/100 , b = 3000 x30 directions and 1 b=0). *Tractography and Motor Tract analysis:* Both the DWI and fMRI series were eddy current corrected, the fMRI series were motion corrected and the fMRI 'z score' maps calculated by the Siemens VB 15 software before being transferred to an image processing workstation. MRTrix [3] was then used to perform a CSD (lmax=8) computation of fibre orientation distribution function (ODF) and a DTI calculation fibre orientation on a voxel by voxel basis. Tractography was performed by seeding the motor tracts based on the eloquent fMRI regions closest to the enhancing tumor and tracking to a target ROI at the top of the peduncle. This was performed for the three fMRI stimuli using all algorithms in MRtrix software [3]. The algorithm was set to initiate a total of 100,000 tracks each time. Maps of track count per voxel were then calculated in the same resolution as the DWI data series. The TVI (%) was then calculated and a paired ttest was used to compare algorithms for a total of 6 seed/target combinations.

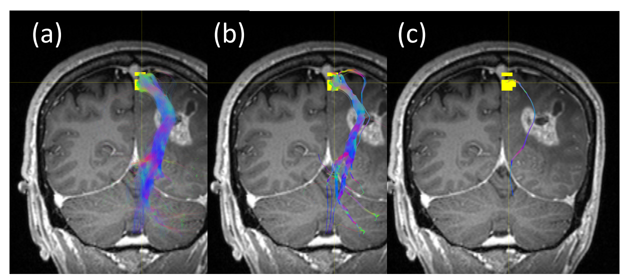

Fig.1: Comparison of tracking algorithms from peduncle to foot eloquent motor cortex. (a) SDPROB, (b) SDST, and (c) DTST. fMRI seed is shown in yellow.

Results: As can be seen visually in Fig.1 the track number and volumes generated by SDPROB are typically greater than those generated by SDST and DTST. In addition then generally intersect more completely with the eloquent cortex (yellow) determined by fMRI. The TVIs were compared statistically and are represented in in Fig: 2. It was found that SDPROB tracks had significantly ($p<0.01$) greater TVIs (62±17%) than those generated from SDST (33±15%) and DTST (15 ±14%).

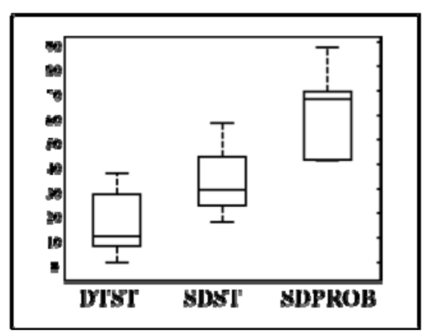

Fig.2: Box plot comparison of TVI (%) for the three tracking algorithms

Conclusions: SDPROB was found to be significantly ($p<0.01$) superior to both SDST and DTST algorithms for mapping the motor pathway to the eloquent motor cortex. These results show that tractography algorithms utilizing methods that can account for complex fiber pathways are likely to give superior prospective neurosurgical guidance for brain tumor resections near eloquent areas of the motor cortex. Due to the small sample size we are currently in the process of confirming these results in a larger prospective imaging trial.

References: **[1]** Behrens TEJ et al, Nat Neurosci 2003;6:750. **[2]** Tournier J-D et al, NeuroImage 2007;35:1459.
[3] MRtrix software package (http://www.brain.org.au/software/)