Rapid semiautomatic segmentation of motor pathways is indicative of hemiparesis in patients with intracranial tumours

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Introduction

Magnetic resonance is currently the imaging modality of choice when investigating patients with intracranial tumour; however conventional magnetic resonance imaging (MRI) techniques provide little information regarding the integrity of the white matter tracts or their position relative to the tumour. These tracts are of great functional importance and this spatial information would be of benefit to the neurosurgeon when planning surgical resection. Diffusion tensor imaging (DTI) and white matter tractography can demonstrate white matter tracts in vivo [1]. These techniques may be used to demonstrate the location and apparent effect of a tumour in relation to local white matter pathways [2]. Previously 'regions of interest' have been drawn to define white matter pathways [3]. This technique invariably requires a large amount of user interaction, apriori knowledge and time, placing it beyond the scope of routine clinical practice. A recently developed algorithm has enabled us to dramatically reduce the time required to perform white matter tractography and allows motor pathway segmentation with virtually no apriori knowledge or user interaction required. Using a single standardised voxel seed point, a single fibre is derived by tracking and subsequently combined with all other statistically similar fibres present to automatically segment the motor pathways [4]. Although white matter tractography has to some extent been validated by comparison with anatomical brain images [5] there has been little to validate tractography functionally. Here we present the results when applied to 25 patients with intracranial tumour, 10 of whom presented with a significant hemiparesis, in an attempt to demonstrate the rapidity and ease of this algorithm as well as validate motor pathway segmentation by comparison with motor function.

Methods

MRI data acquisition

All patients were scanned on a 1.5 T General Electric Signa MRI system with maximum field gradient strength $22mTm^{-1}$. Diffusion tensor imaging was achieved using a single shot echo planar sequence with 12 diffusion sensitised directions as described previously [2]. Whole brain coverage was achieved with two interleaved acquisitions comprising 25 slices each. In plane resolution was 2.5mm and through plane resolution was 2.8mm, providing near isotropic voxels.

Fibre Tracking

For each patient, subvoxel principal direction tractography was performed by interpolation of the tensor field. Tractography was initiated from the centre of every voxel with a fractional anisotropy (FA), of greater than 0.05. Fibre track propagation was terminated upon reaching a voxel with an FA of <0.05, or when the difference in angle between two contiguous voxels was >90 degrees. The geometry of the individual fibres propagated from each voxel were computed and stored at a voxel level. Using the FA image as a guide, a single voxel was chosen bilaterally within the anterior rostral medulla. Each voxel was chosen simply as being that voxel centrally placed within the area of high FA. (See fig. 1) The geometry of the fibre previously computed for that seed voxel was compared with every other fibre in the entire image and grouped together with those that were statistically similar. This group of fibres was then grown using a technique similar to that presented previously [4], where additional fibres were included if they were statistically similar to the mean of the group. This process was carried out iteratively until there was no further increase.

Patients

Between March and October 2004 25 patients, 18 male and 7 female patients with an average age of 48 (25-73) yrs underwent DTI prior to treatment for their supratentorial tumours. The study was approved by the local area ethics committee and all patients gave their informed consent. Patients were included if their tumour was located close to the descending motor pathways.

Figure 1 Single Voxel Seed Points

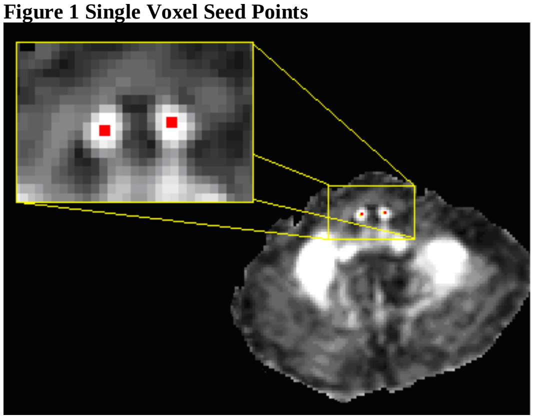


Figure 2 Motor Tract Distortion

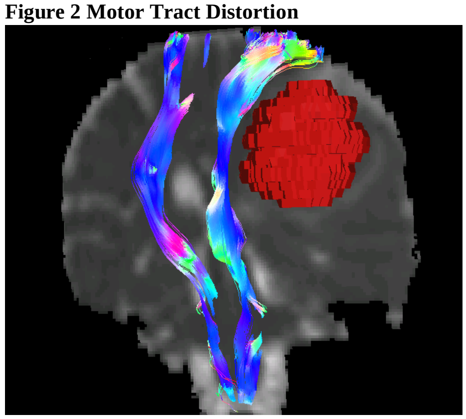
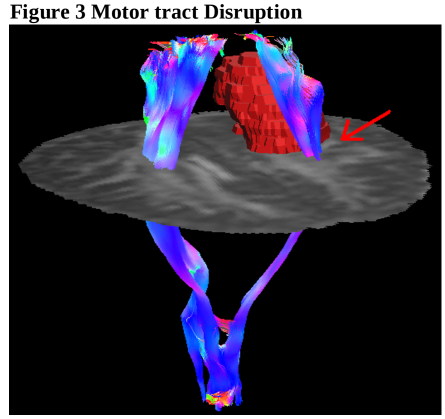


Figure 3 Motor tract Disruption



Results

10 of the 25 patients had a clinically demonstrable hemiparesis. There were 6 glioblastomas, 5 metastatic tumours, 6 grade 2 astrocytomas, 2 meningiomas and 6 other various tumours. All of those patients with a demonstrable hemiparesis were shown on white matter tractography to have a clearly distorted (Fig.2) and / or disrupted motor pathway (Fig. 3). There were 3 cases where although the patient appeared to have normal motor function there was a reduction in the size of the motor pathways on tractography. This represents a 100% sensitivity of motor tract disruption for hemiparesis with a specificity of 80%.

Discussion

This study has shown that a single voxel tractography growing algorithm enables an extremely rapid segmentation of the descending motor pathways with minimal user interaction or apriori anatomical knowledge; this brings the technique closer to being practical within a clinical setting. We have also shown that motor pathway disruption is highly sensitive to the presence of a clinically demonstrable hemiparesis. These results further validate white mater tractography and motor pathway segmentation as a functional imaging tool as well as clearly demonstrating its potential for surgical planning.

References

[1] Mori et al. Magn Reson Med, 2002, 47:215-223
[2] Clark CA, et al., NeuroImage 20 (2003) 1601-1608
[3] Mori et al., 1999. Annals of Neurology 45(2): 265-269
[4] Barrick TR et al. ISMRM, Kyoto #619
[5] Stieltjes et al. NeuroImage, 2001, 14:723-35

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