Identifying Glioma Infiltration of White Matter using Diffusion Tensor Imaging: An MR Image-Guided Biopsy Study

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Background

The propensity of gliomas to infiltrate surrounding white matter tracts is a major factor in the failure of current treatments. Current imaging methods are unable to identify the tumour margin accurately and this has major implications in both surgical and radiotherapy planning. Diffusion tensor imaging (DTI) is sensitive to subtle white matter disruption and can detect a larger abnormality around gliomas than T2-weighted imaging[1]. Using diffusion tissue signatures can further classify white matter involvement into disruption, infiltration and displacement[2]. The aim of this study was to correlate these markers with tumour histology using image-guided biopsies.

Materials & Methods

Fifty patients with gliomas were imaged at 3T using a a single-shot, spin echo, echo planar DTI sequence (5 b-values, 12 directions). The DTI data was processed using an in house program implemented in MATLAB and maps of *fractional anisotropy* (FA), *p* (the isotropic component of the diffusion tensor) and *q* (the anisotropic component of the diffusion tensor) as well as directionally encoded colour maps were generated. Regions of interest were selected that corresponded to white matter disruption, infiltration and displacement as classified by Witwer[3]. The differences between the *p* and *q* values for each region compared to a matching region from the opposite hemisphere was determined for all regions of interest.

Sixteen patients (mean age 48.5) requiring biopsy of a presumed intracranial glioma were imaged pre-operatively using a T_2-weighted, a gadolinium enhanced 3D-SPGR sequence as well as the DTI sequence. Maps of the isotropic component *p* and the anisotropic component *q* were generated and coregistered to the SPGR sequence used for image-guidance. All patients underwent image guided biopsies with samples taken from the selected target and then at centimetre intervals. Regions of interest that corresponds to the area sampled (10 x 4 mm) were determined at each of the biopsy sites and the T_1 and T_2-weighted appearances noted. Diffusion tissue signatures were calculated for each site and compared to a region from the normal contralateral hemisphere. All biopsy samples were examined by an experienced neuropathologist and classified as purely tumour, normal tissue infiltrated with tumour or normal brain.

Results

Displaced white matter tracts demonstrated no difference in the tissue signature. Tracts infiltrated with tumour showed an increase in the isotropic value of *p* of greater than 10% of the baseline, but no change in *q*. Tracts disrupted by tumour had a decrease in the anisotropic component of more than 12% compared to the baseline value.

A total of 63 regions were biopsied. Half of the biopsy tracts included normal brain. DTI could accurately identify tumour in all of the 37 biopsy sites that contained pure tumour. T_1- and T_2- weighted sequences failed to identify tumour in two cases. In the 13 samples of tumour infiltrated brain, T_1-weighted imaging could identify 6/13 and T_2-weighted could identify 7/13. DTI tissue signatures correctly identified tumour infiltration in 12/13 cases. There was one false positive in an area of normal brain with a perivascular mononuclear infiltrate. Overall the tissue signatures had a sensitivity of 96% and specificity of 85%.

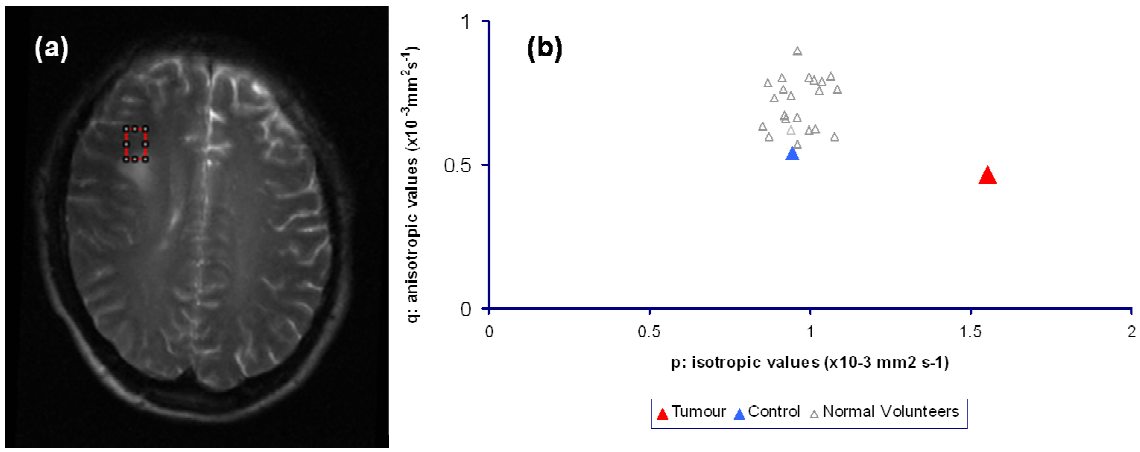

Figure: (a) A biopsy site in a 54-year old woman with an anaplastic oligoastrocytoma. This biopsy is taken outside the area of abnormality on the T_2-weighted image. (b) A tissue signature of this region of interest. Compared to the control region (in blue) the tumour (in red) had an increase in the *p* component of more than 10% but a *q* component within 12% of the control. This suggests tumour infiltration of a white matter tract which was confirmed on histology. DTI is able to identify this region in an area considered normal on T_2-weighted imaging.

Conclusions

Diffusion tensor tissue signatures are more sensitive at identifying tumour infiltration than conventional T_1 or T_2-weighted sequences. Using the tissue signature method, you can define a region around a tumour with a reduction in the anisotropic component (*q*) that is due to tumour disruption, and an area outside this of increased isotropic component (*p*) that is due to tumour infiltration. This may provide a useful technique for more individualised radiotherapy planning.

References

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3. Witwer BP et. al. *J.Neurosurg.* (2002), 97: 568-575.