DTI and tractography metrics discriminate between brain tumour types in vivo

T. J. Byrnes[1,2], T. R. Barrick[1], C. Ladroue[3], B. A. Bell[2], C. A. Clark[1]

[1]Clinical Neurosciences, St George's University of London, London, United Kingdom, [2]Academic Dept. of Neurosurgery, St George's University of London, London, United Kingdom, [3]Basic Medical Sciences, St George's University of London, London, United Kingdom

Introduction

Brain tumour diagnosis is necessary to determine management; however surgical biopsy is not without significant risk of morbidity and mortality. A non-invasive diagnostic test could reduce the necessity for biopsy and its associated risks. Various MRI sequences have been studied in an attempt to determine tumour type without biopsy. Diffusion imaging has been shown to differentiate between brain tumour and non-neoplastic lesions [1]. Attempts to use diffusion metrics to discriminate between tumour types has led to contradictory results, and although significant differences between various DTI metrics and particular tumour types have been reported [2], there is a large spread within the data making its predictive ability of little diagnostic value. Using a multiple variable approach we demonstrate the ability of DTI metrics when combined with tractography to discriminate between the 3 most prevalent brain tumour types, namely glioblastoma, meningioma, and metastasis.

Methods

MRI data acquisition

All patients were scanned on a 1.5 T General Electric Signa MRI system. DTI was achieved using a single short echo planar sequence (EPI) with 12 diffusion sensitised directions as described previously [3]. In plane resolution was 2.5mm and through plane resolution was 2.8mm, providing near isotropic voxels. The diffusion tensor was determined for each image voxel and the tensor was diagonalised. Mean diffusivity (MD), fractional anisotropy (FA) [4], and the tensor shape metrics, linear, planar and spherical [5] for each voxel were calculated.

Fibre Tracking

Subvoxel principal direction tractography was performed by interpolation of the tensor field. Tractography was initiated from the centre of every voxel with an FA of greater than 0.05. Fibre track propagation was terminated upon reaching a voxel with an FA of <0.05, no angular threshold was applied. The number of individual streamlines passing through each voxel (streamline density) was computed and stored at a voxel level [6].

Patients

Between March 2004 and October 2005 74 brain tumour patients were studied. Of these, 36 patients (12 female and 24 male patients with an average age of 60 (27-73) yrs) were proven histopathologicaly to be glioblastoma, meningioma or metastasis and were included in the study. The study was approved by the local area ethics committee and all patients gave their informed consent. Using the EPI T2 image, regions of interest (ROI) were drawn around the tumour, identified as the limit of enhancement on the T1 post contrast image where available, and the oedema, identified as the T2 weighted high-intensity signal abnormality surrounding the tumour.

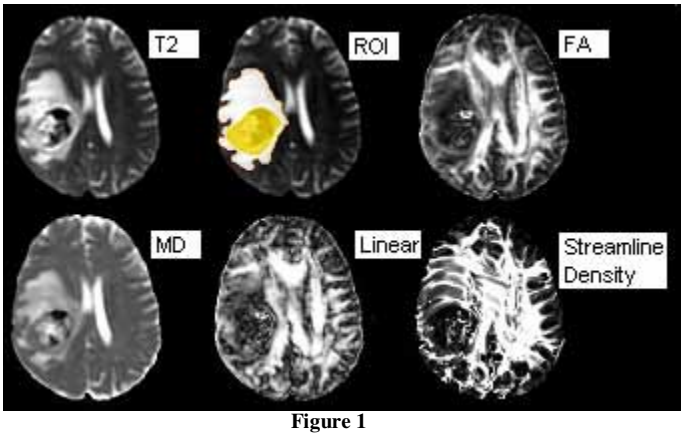

Figure 1

Statistical analysis

For each of the 36 patients included, the mean FA and MD were calculated for both the tumour and oedema regions. The mean tensor shape components were also calculated along with the mean streamline density (figure 1). After being grouped together into specific histological tumour types these means were tabulated with SPSS for Windows (Rel. 11.0.1. 2001. Chicago: SPSS Inc.) and a multivariate analysis was performed to identify those which were most statistically different between the groups. The three tumour types, described by the DTI metrics, were subjected to principal component analysis and subsequently to a linear discriminant analysis using the derived principal components. Group centroids were calculated and a casewise group membership prediction was performed using a squared Mahalanobis distance technique on the data. This was repeated on cross validated data using the 'leave one out' method[2] where one case is iteratively omitted from the dataset and a linear discriminant analysis performed. The omitted case is then compared to the group centroids and a classification of that case is then determined.

Results

The DTI metrics identified from the multivariate analysis separating the tumour types most significantly were MD-tumour, linear-tumour, MD-oedema, FA-oedema and streamline density. The first 3 principal components, derived from these variables, cumulatively described 90.0% of the data. The tumour data are plotted by these three components (figure 2). The results of the casewise predicted group membership analysis for the cross validated data are shown (table 1). With all data included in the analysis 86.1% of cases were correctly classified i.e. closest to the appropriate tumour type centroid. Cross validation using the 'leave one out' method resulted in correctly predicting the histological tumour type in 80.6% of cases with correct identification of glioblastoma in 69%, meningioma in 75% and metastasis in 100% of cases.

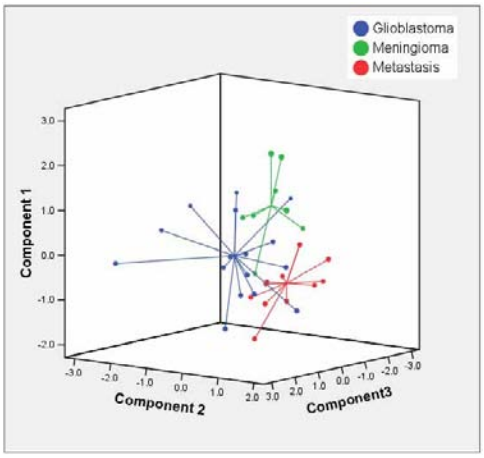

Figure 2

Classification Results

		Pathological Diagnosis	Predicted Group Membership			Total
			Glioblastoma	Meningioma	Metastasis	
Cross-validated	Count	Glioblastoma	11	0	5	16
		Meningioma	0	6	2	8
		Metastasis	0	0	12	12
	%	Glioblastoma	**68.8**	0.0	31.3	100
		Meningioma	0.0	**75.0**	25.0	100
		Metastasis	0.0	0.0	**100.0**	100

Table 1

Discussion

These results indicate that DTI and tractography metrics, when combined, can be used to discriminate between glioblastomas, meningiomas and metastasis. The technique correctly predicts glioblastoma in 69%, meningioma in 75% and metastasis in 100% of cases. These data indicate that DTI and tractography metrics are useful in the diagnosis of patients with brain tumour and could potentially reduce the requirement for invasive biopsy.

Acknowledgements Cancer Research U.K. have funded this work Ref: C8807/A3870

References

[1] Ebisu T, et al., Magn Reson Imaging. 1996;14:1113-1116 [2] Guo AC, et al., Radiology. 2002;224:177-183 [3] Clark CA, et al., NeuroImage. 2003;20:1601-1608
[4] Basser PJ, et al., Biophys J. 1994;66:259-267 [5] Westin CF, et al., Med Image Anal. 2002;6:93-108 [6] Barrick TR et al. Proc. ISMRM. 2004:619