Using Quantitative MR Diffusion Tensor Imaging to Predict Post-surgical Outcome of Brain Tumors: A Feasibility Study

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Introduction

Information of tissue microstructures and prediction of post-surgery outcome of brain tumors are invaluable clinically. However, the prediction remains infeasible if only morphological imaging is involved. Until recently, non-invasive mapping of tissue microstructures as well as tumor grading has been developed and proposed by using MR diffusion tensor imaging (DTI) (1, 2). Diffusivity of water molecules in tissues is altered due to hindrance by the presence of complex microstructural barriers, such as cell membrane, tissue barriers, or myelin sheath, and consequently, the magnitude and directionality of echo signal at each pixel in three-dimensional space are various. To predict post-surgical outcome of brain tumor, tissue contents and diffusivity of peri-tumoral regions might serve as a clinical criterion. This study focused on peri-tumoral tissues with the hypothesis that FA and ADC indicate tissue integrity and water content of peri-tumoral regions and can be used to predict the post-surgical outcome.

Materials and Methods

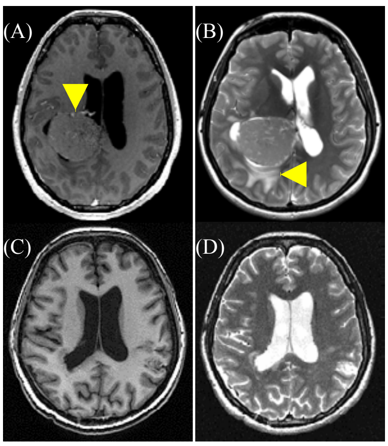
Patients Four patients (44, range 33-61 y/o; 4 male and 1 female) with brain tumors (3 meningiomas and 2 anaplastic astrocytomas-AA, all surgical and pathological proved) were recruited in this study (Table). All patients gave informed written consent following the guidelines of institutional review board.

MR Imaging and Image Processing MR data were acquired using a 1.5T MR system (Excite II; GE Medical Systems, Milwaukee, Wis, USA) with an 8 channels head coil before and 1 to 8 weeks months after tumor resection. Conventional T1-weighted imaging (T1W) before and after the Gd-DTPA administration (0.1 mmol Gd-DTPA/kg of body weight) with TR/TE= 550/15 msec, 24x24 cm field of view (FOV), 325x256 matrix and pre-contrast T2-weighted imaging (T2W) with TR/TE = 3000/90 msec using fast spin-echo sequences with same pixel size were routine sequences. DTI was performed by using single-shot spin-echo echo planar imaging sequence with the same FOV used on T1W, 2 mm slice thickness, 128 x 128 matrix. Parallel imaging was employed by using the principles of sensitivity encoding with an acceleration factor of 2 to hasten the acquisition and to shorten the effective echo time. With diffusion gradients applied in 13 noncollinear directions with TR/TE = 17000/69 ms, b = 1000 s/mm^2, nex = 6, the diffusion gradients in x, y, and z direction were equally distributed on a sphere according to the minimal energy arrangement of electron distribution. With 2 reference images, the spherical symmetric diffusion tenor MR imaging sequence was used to minimize the cross-term effect and to optimize the signal-noise-ratio (3, 4). All MR images were acquired in less than 50 minutes.

All raw data were transferred to a computer workstation for analysis using programs in Borland C++ that were developed in house. The regions of interest (ROI) were delineated by one of a same experienced neuroradiologist. With slice-to-slice basis, on T2W peri-tumoral, white matter irregular shape, edema around gadolinium-enhanced tumor mass depicted on T1W was delineated as ROI. FA and ADC of the selected ROIs were further calculated.

Results

The meningiomas were completely resected. Their pre-surgical peri-tumoral mean FA in DTI was, respectively, 0.29±0.05 and 0.19±0.05. Peri-tumoral edema of the former vanished completely after surgery while the later had residual edema. Clinically the former completely recovered and the later had remaining focal neurological deficits. For the two anaplastic astrocytomas, their pre-surgical peri-tumoral mean FA was, respectively, 0.18±0.02 and 0.17±0.03. Complete tumor resection was able to achieve in none of them. Post-surgical peri-tumoral mean FA of the former tumor was 0.19±0.02. Extra-axial tumors (meningiomas) had higher FA in peri-tumoral edema. They had higher opportunity to ***normalize*** after tumor resection and the clinical outcome is better. On the contrary, intra-axial tumors (anaplastic astrocytomas), had lower FA in peri-tumoral edema. Its post-surgical FA did not deviate from the pre-surgical one and the post-surgical peri-tumor edema shows no obvious changes on T2W, neither. Clinically the outcome is worse.



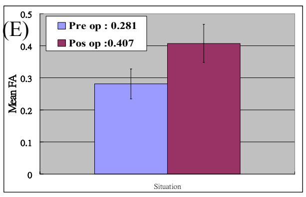
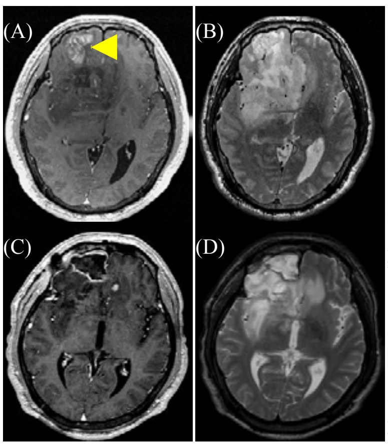


Figure 1, A) Gd-T1W of meningioma patient shows a minimally enhancing tumor (arrow) in the occipital horn of right lateral ventricle. B) T2W shows the peri-tumoral edema (arrow) in the white matter of right parietal-occipital. C, D) post-surgical images show total tumor removal and disappearance of peri-tumoral edema. E) a plot of FA at the peri-tumoral regions before (22 ROIs) and after (10 ROIs) tumor resection. The mean FA of peri-tumoral edema was recovered from 0.281 ± 0.046 to 0.407±0.059



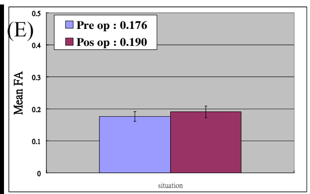


Figure 2, A) Gd-T1W of AA patient, the enhancing part (arrow) in the right frontal pore indicates the portion of AA with blood-brain- barrier break-down. B) T2W shows the abnormal high signals of tumor and surrounding tissues. C, D) post-surgical images show partial removal of tumor. The signal abnormalities in right frontal region show no obvious interval changes compared to pre-surgical ones. E) a plot of FA at the peri-tumoral regions (25 ROIs) before and after tumor resection. The mean FA of peri-tumoral edema was recovered from 0.176±0.015 to 0.190±0.018.

Conclusion

In addition to morphological diagnosis (by conventional MR imaging), metabolic diagnosis (by MR spectroscopy) and microcirculation (by perfusion MR imaging and blood oxygenation level dependent, BOLD, imaging) evaluation, MR provides a novel dimension on studying tissue environment on microscopic level by DTI. FA values derived from DTI reflect interstitial characters of peri-lesional tissues of brain tumors (5). Low FA indicates interstitial tumor infiltration and tissue injury and, vice versa, high FA indicates better tissue integrity. DTI can be used not only as pre-surgical trajectory guidance but also used as a predictor of post-surgical outcome with the insight into peri-tumoral tissue integrity.

Acknowledgements

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