IMAGES OF RESTRICTED WATER IN BRAIN WITH APPLICATIONS TO NEUROSURGERY

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OBJECTIVE:

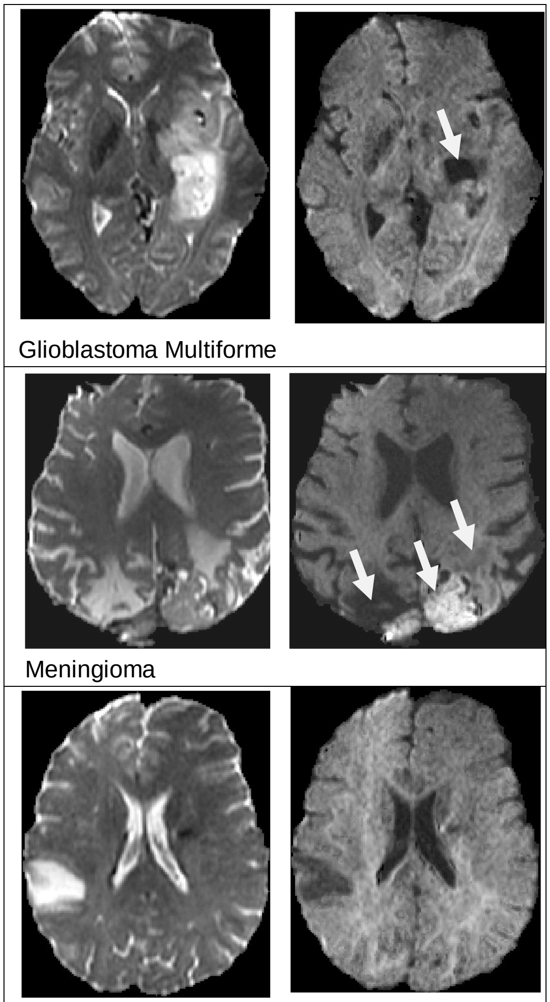
To improve DTI fiber tracking for the preoperative planning of brain tumor surgery.

HYPOTHESES:

1. Viable areas of white matter tracts retain a defined intra-axonal space even if the surrounding tissue is edematous or partially infiltrated by tumor or both. These pathologies may significantly reduce the measured diffusion anisotropy rendering conventional DTI-based fiber tracking problematic, but if a directionally anisotropic restricted water pool on the μm scale can be identified, intact tracts probably still exist.
2. Restricted diffusion in brain on the micron scale manifests as non-attenuating substrate when long diffusion gradients are applied. Typical clinical diffusion imaging utilizes gradient pulses of approximately 20 ms or more, that fall into this category. For details see Ref. [1].
3. DTI acquired with multiple b-values can be analyzed to yield the non-attenuating signal fraction. This signal fraction is assumed to originate in restricted water compartments, such as axons.

METHODS:

Twelve patients with brain tumors were scanned preoperatively under a surgical planning protocol that included both fMRI and DTI. The eigenvectors (i.e. tract directions) were determined from 36 isotropically distributed (b=800 s/mm^2) gradient directions. For a better fit to heterogeneous white matter, a constrained two tensor model was applied. The DTI scan included a small number of directions with higher b-values, up to 2400 s/mm^2. The known eigenvectors were used to determine the diffusion curves parallel and perpendicular to the tract in each voxel. The fraction of the signal representing restricted intracellular water was extracted using the analysis presented in Ref. [2], based on fitting the perpendicular diffusion to a monoexponential + baseline where the baseline is postulated to represent the non-attenuating signal fraction originating in intracellular water. The portion of the signal originating in restricted environments was reconstructed by multiplying the restricted water fraction by the T_2-weighted signal.



Glioblastoma Multiforme

Meningioma

Anaplastic Astrocytoma

Left: EPI-T_2 **Right:** Intracellular Signal (restricted water: RW)

RESULTS:

Three primary brain tumors are shown in the figure. On the left the baseline spin-echo EPI, and on the right the calculated signal fraction from intracellular water, termed RW signal (restricted water). Note that this signal is also T_2-weighted because it is derived from the T_2-weighted signal. In the glioblastoma, an area of complete tissue destruction (arrow) is surrounded by heterogeneous tissue, although some of the lesion appears to have normal levels of intracellular water. The meningioma exhibits three main areas – near the brain surface a bright area that is unlike any other brain tissue, another area that is bright on T2 but dark on the RW image, indicating the absence of normal structure, and an area that is bright on T2, and relatively normal on RW. In the case of the anaplastic astrocytoma, the whole lesion area appears dark on RW.

CONCLUSION:

A new contrast mechanism, not available from other MRI methods, is demonstrated. It may prove a useful tool in separating recurrent tumor from radiation necrosis and for biopsy guidance – currently it is under investigation for use in differentiating pathologies and for assisting DTI-based fiber tracking through edema. In and around lesions, normal RW values may indicate that tracking should persist even if anisotropy is low.

REFERENCES:

[1] P. P. Mitra and B. I. Halperin, "Effects of finite gradient-pulse widths in pulsed-field-gradient diffusion measurements," *J. Magn. Reson. Series A,* vol. 113, pp. 94-101 , 1995.

[2] S. Peled "New Perspectives on the Sources of White Matter DTI Signal", *IEEE TMI* 2007 , 26(11) pp. 1448-1455.

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