Does Increased Fractional Anisotropy in Brain Abscess Imply White Matter Tracts on DTI?

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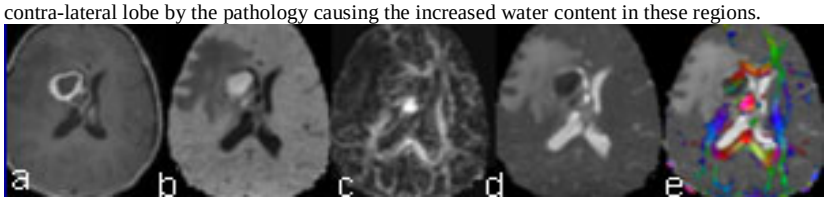
Introduction: Diffusion is anisotropic in white matter fiber tracts, as axonal membranes and myelin sheaths present barriers to the motion of water molecules, in directions not parallel to their own orientation. The direction of maximal diffusivity has been shown to coincide with the white matter tract information[1,2]. A brain abscess is characteristically defined as a focal suppurative process within the brain parenchyma. It forms important differential diagnosis with other tumor and non-tumor ring enhancing brain lesions. Although most abscesses show restricted diffusion, there are reports showing high diffusivity in the treated abscesses and restricted diffusion in cystic metastases[3]. We report remarkably high FA from the cavity of brain abscess in 9 patients with restricted mean diffusivity in comparison to non-abscess cases. An attempt is made to explain this unusual observation that is being described for the first time in the literature.

Subjects and Methods: Nine pyogenic abscesses, 5 low-grade astrocytoma and 2 neurocysticercosis patients formed the study group. There were 10 males and 6 females aged 4-55 years. 10 healthy age and sex-matched normal volunteers were also imaged as controls. Brain imaging was performed on a 1.5 Tesla MR Scanner using single-shot echo-planar dual spin-echo sequence with ramp sampling. The diffusion weighting b-factor was set to 1000 s mm^{-2}, TR ~ 8 sec, TE ~100 ms. A total of 20-34 axial sections were acquired with a slice thickness of 3 mm, no gap, FOV=240 mm×240 mm and an image matrix of 256×256. The diffusion tensor encoding used was the balanced, rotationally invariant icosahedral scheme with 21 uniformly distributed directions over the unit hemisphere[4].

Data Processing and Quantification

As a part of pre-processing, collected raw images were cropped and stripped using a semi-automated procedure to remove the scalp for isolating the brain. The DWI data were spatially filtered with a 3x3 median window. Subsequent DTI processing uses Automated Image and Registration (AIR) package to correct the data for distortion. The distortion corrected data were then interpolated to attain isotropic voxels and decoded to obtain the tensor field for each voxel. The analytical diagonalization method was used to obtain eigenvalues and orthonormal eigenvectors of the tensor field data. The tensor field data and eigenvalues were then used to compute the DTI metrics. The ROI placement on the lesions was based on the FA maps overlaid on the MD with a cut-off value of 0.20 so that voxels could be separated between the ones with FA≥0.2 and FA<0.2 for all the cystic lesions. In addition, the same ROIs were placed on the perifocal edema and the corresponding contra-lateral normal appearing parenchyma as depicted by T2W images. Size of the ROIs was guided by the lesion size and it was always more than 3x3 pixels in all the cases and typically 8x8 pixels with shape varying from elliptical to rectangular. FA and MD from the whole brain from 3 healthy subjects were also quantified for the purpose of comparison.

Results: The viable leukocyte count varied from 7000-18000 in all the abscess cases. There was no viable cell visible on microscopy in the fluid obtained from the tumor cavity. The changes in FA at different locations of the abscess, cystic tumors, NCC, corresponding contra-lateral normal appearing white matter, and from the normal healthy individuals are plotted against MD. Part of the abscess with FA more than 0.2 and less than 0.2 showed mean FA= 0.385 $\pm$ 0.04 with MD = (0.979$\pm$ 0.08) $x10^{-3}$ mm^2 sec^{-1}, and FA = 0.132 $\pm$ 0.01 with MD = (0.876 $\pm$ 0.12) $x10^{-3}$ mm^2 sec^{-1} respectively (fig. 1 a-e). The cystic tumors and NCC showed very high MD = (2.806 $\pm$ 0.25) $x10^{-3}$ mm^2 sec^{-1}, (2.654 $\pm$ 0.35) $x10^{-3}$ mm^2 sec^{-1} with low FA values ~ (0.108 $\pm$ 0.037 and 0.08 $\pm$ 0.01) respectively. The MD values were towards the higher side compared with the normal healthy subjects and the normal values reported in the literature. This is probably due to voxel contamination with cerebrospinal fluid and probably due to the effect of pressure on the contra-lateral lobe by the pathology causing the increased water content in these regions.



Discussion: The effect of cerebral neoplasm on the white matter tracts has been described using DTI as compressive, discontinued in the region of edema or tumor or disrupted due to tumor infiltration. This information has been found to be useful for the purpose of tumor resection. In this study we observed markedly increased FA in the cavity of the abscess with different orientations that was not observed in the cavity of the cystic astrocytomas and neurocysticercosis. The FA values are as high as the normal white matter with orientation apparently suggesting an oriented structure within the cavity. Histologically, there was no structure other than the inflammatory cells, necrotic debris, proteins and amino acids. We propose that the inflammatory cells in the abscess cavity become oriented and organized resulting in high diffusion anisotropy. We postulate that the regions with high FA values in the cavity of the abscess contain aggregated (clumped) leukocytes due to the presence of adhesive molecules, which to get up regulated in the presence of bacteria. However, the current observation challenges the traditional view that brain anisotropy usually represents myelination and axonal packing and calls for some caution in the interpretation of DTI data. Larger variation in FA values without a great difference in MD of the abscess cavity suggests that FA does not have strong relationship with MD in the abscess model. In conclusion, the present study demonstrates that brain abscess cavity shows regions of increased FA values with restricted mean diffusivity compared to other cystic intracranial lesions. With an increasing use of DTI in surgical planning of brain tumor resection, one may become more careful in interpreting these changes as oriented axonal fibers.

References:

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