

HIGH B VALUE DIFFUSION MRI IN STROKE

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Synopsis

Diffusion tensor imaging detects reduction in diffusion anisotropy in acute and chronic white matter ischemic lesions. However, it is not clear whether this anisotropy reduction is due to damage to the white matter or structural changes in the tissue. In this work we have used high-b-value diffusion weighted imaging in order to study this issue. We have found that the slow diffusing component is isotropically increased in acute stroke areas, which might originate from increased tortuosity in the extra cellular space. Four weeks after stroke, the diffusion anisotropy at high-b-value approached control value while the low-b-value DTI was still reduced.

Introduction

Stroke is one of the most studied pathologies using diffusion weighted MRI (DWI) as the apparent diffusion coefficient (ADC) is markedly reduced minutes after stroke¹. Increased extra-cellular water tortuosity and increased intra-cellular volume fraction are believed to be the main causes for the ADC reduction¹⁻³. Nevertheless, there is still an on going debate regarding the relative contribution of these two factors. In addition it was found that diffusion anisotropy as measured by diffusion tensor imaging (DTI) is reduced in white matter ischemic areas⁴. The origin of this anisotropy reduction is not clear.

High b value diffusion MRI was shown to produce non-mono-exponential signal decay in neuronal tissues⁵. The slow diffusing component, apparent only at high b value, is believed to originate from restricted water diffusion⁶. It was suggested that in healthy tissue the main contributor for the restricted diffusion is water diffusion in the axonal compartment⁶. The high specificity of the DWI signal at high b value to the axonal water makes it more sensitive to white matter changes as was shown in animal model of myelination⁷ and demyelination⁸ and in multiple sclerosis in humans⁹. In those works it was also shown that q-space analysis enables the extraction of the displacement distribution profile which emphasizes the contribution of the slow diffusing component⁷⁻⁹. In this work we have used high b value diffusion MRI for studying white matter integrity following stroke at the acute and chronic stages.

Methods

MRI WAS PERFORMED ON A 1.5T GE SIGNA MRI SCANNER. THREE PATIENTS WERE EXAMINED AT THE FIRST 48 HOURS AND 4 WEEKS FOLLOWING ISCHEMIC STROKE (2 WITH SUB-CORTICAL AND 1 WITH CORTICAL LESIONS). THE MRI PROTOCOL INCLUDED T₁, T₂ AND FLAIR IMAGES AS WELL AS MR ANGIOGRAPHY, PERFUSION WEIGHTED IMAGING, LOW B VALUE DTI AND HIGH B VALUE DWI. THE HIGH B VALUE IMAGES WERE OBTAINED FROM A SERIES OF 16 DIFFUSION WEIGHTED ECHO PLANAR IMAGES (DWEPI) WITH B_{MAX} OF 14,000 S/MM² PERFORMED AT 6 GRADIENT DIRECTIONS (XY,XZ,YZ,-XY,-XZ AND Y-Z). THESE DIFFUSION EXPERIMENTS WERE PERFORMED WITH THE FOLLOWING PARAMETERS: TR/TE=2000/167MS, $\gamma/\beta=72/65$ MS AND EFFECTIVE MAXIMAL GRADIENT STRENGTH OF 3.1 GAUSS/CM. Q-SPACE DISPLACEMENT AND PROBABILITY IMAGES WERE COMPUTED FROM THE HIGH B VALUE DATA SET AS DESCRIBED BEFORE⁹. CONVENTIONAL DTI WERE ALSO ACQUIRED AT THE AFOREMENTIONED GRADIENT DIRECTIONS WITH THE DWEPI PULSE SEQUENCE WITH B VALUE OF 1000 S/MM² AND THE FOLLOWING PARAMETERS: TR/TE=6000/98MS, $\Delta/\delta=31/25$ MS.

Results

Figure 1 shows FLAIR, ADC, fractional anisotropy, and high b value q-space displacement images taken 24 hours post stroke. Figure 2 shows the same data set on the same subject taken 4 weeks post stroke. The region of interest showed on the FLAIR images represent a hyperintense subcortical white matter area that was damaged due to stroke. In that area a reduction in the fractional anisotropy is observed at 24 hours, which seems not to improve at 4 weeks (see table 1). ADC of that area is reduced at 24 hours and increases beyond control values at 4 weeks. The high-b-value DW images reveal an increase in the relative population of the slow diffusing component at any measured direction at the acute stage. Indeed, q-space displacement values shows reduction in the mean displacement at 24 hours as expected for acute edematous tissue and a reduction in the high-b-value anisotropy (table 1). In contrast, at 4 weeks, although the FA values are still low and the ADC values are already high, the displacement values and the high b value anisotropy approaches the normal values (see table 1).

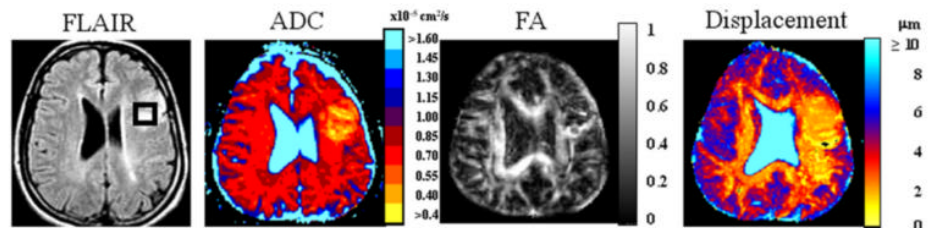


Figure 1: FLAIR, ADC, FA and q-Space Displacement imaging taken 24 hours after stroke

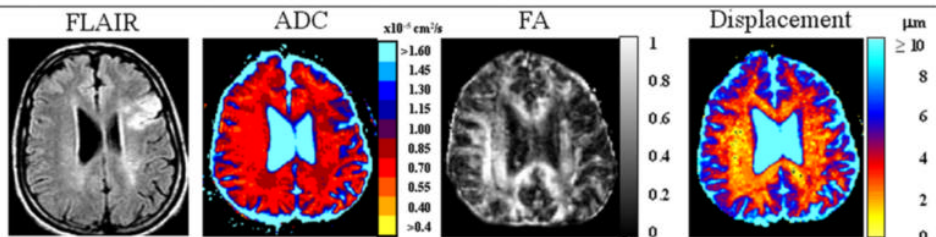


Figure 2: FLAIR, ADC, FA and q-Space Displacement imaging taken 4 weeks after stroke

Discussion

High b value diffusion imaging is very sensitive to the existence of restricted diffusion. In healthy tissue, the signal at high-b-values was tentatively assigned to restricted water diffusion within neuronal fibers⁶. In this study we found that in the acute stage of stroke there is an increase in the amount of restricted diffusion as the slow diffusing component, observed at high b values, becomes apparent at any measured direction. This may be a result of shrinkage of the extra-cellular compartment that leads to restricted diffusion that is more isotropic. Four weeks after stroke, the high b value, q-space analyzed images, still reveals significant, anisotropic amount of restricted diffusion, which in this case might be attributed to vital white matter fibers within the ischemic region. At both time points, low-b-value diffusion anisotropy, which is more sensitive to extra-cellular diffusion, show reduced diffusion anisotropy. These results may suggest that high b value diffusion imaging and low-b-value DTI show information on different water populations that might give additive information regarding the pathophysiology of the damaged tissue.

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	CONTROL	STROKE – 24 HOURS	STROKE – 4 WEEKS
ADC (x10 ⁻⁶ CM ² /S)	7.0±0.7	5.8±0.7	9.8±0.8
FA *	0.45±0.04	0.12±0.05	0.17±0.06
DISPLACEMENT (μM)	8.84±1.24	3.88±0.24	7.45±0.82
σ(DISPLACEMENT) **	0.48±0.07	0.14±0.02	0.40±0.04

*CALCULATED FOR LOW-B-VALUE DIFFUSION TENSOR DATA ** HIGH-B-VALUE ANISOTROPY INDEX CALCULATED FROM THE VARIANCE OF THE DISPLACEMENT VALUES