Assessment Of Slow Diffusion Component Changes In Acute Stroke By Q-Space Analysis

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BACKGROUND Diffusion weighted MRI (DWI) is sensitive to changes of structural and functional status of brain parenchyma. This has been shown to provide complimentary information to conventional contrasts in acute stroke. Imaging of the slow diffusion components is interesting for theoretical considerations and challenging for technical reasons. One way to visualise and analyse slow diffusion is q-space analysis, which extracts structural information without the use of a model. Q-space analysis has shown very promising results in demonstrating various pathologies including inflammatory-demyelinating tissue changes. Although not entirely clear, it has been suggested, that the high sensitivity of the slow diffusion component might be due to the representation of intra-axonal/intra-cellular water diffusion. We developed and implemented sequences and analysis strategies along the lines suggested by Assaf, Cohen et al. and employed high b-value DWI and q-space analysis in acute stroke patients to study the sensitivity and imaging information when compared to other contrasts.

METHODS Standardized MRI was performed in 16 patients with acute stroke (mean time from symptom onset 12.8 h; mean age 66 years) and six normal healthy subjects who served as a control group with a 1.5 T Siemens SONATA system. A standardized MRI protocol was used: 3 localizers, T2w-TSE, and DWI including high b-value measurements for q-space analysis. Spin echo prepared diffusion weighted sequence, 6 directions, 14 b-values in each direction, b-value range: b = 0 - b=8182 s/mm2 by linearly increasing the diffusion gradient amplitude TE/TR = 136/1500, 120x128 matrix Voxel size: 1.875x1.875x4.5 mm. Postprocessing was performed including 2D rigid body motion correction, eddy current correction. Q-space analysis for each direction provided 2 parameter maps: 1. A probability for zero displacement map (the peak intensity of the displacement distribution probability function). 2. the minimum displacement, extracted from the width at half-height given in arbitrary units and m respectively. The maps display the information using a color scaling scheme. The analysis focused on the probability for zero displacement maps. Images were compared for information content in regard to the delineation of anatomical structures and lesions.

RESULTS We found no abnormalities in the conventional and DWI data of the control group. Figure 1 gives an example of q-space analyzed MR images of a normal subject, showing the probability for zero displacement, describing the apparent displacement of water protons in a voxel. The values for the calculated probability for zero displacement is higher in the white matter compared to the gray matter.The acute ischemic lesions in the patient group were categorized into lesions of the subcortical white matter in 10 patients (mainly lacunar, hemodynamic and lenticulostriate stroke subtypes), while in the other 6 cases the cortex was primarily (cerebral embolism) or additionally (territorial stroke) affected. The lesions could be detected on high b-value DWI in every case, however exact lesion delineation differed depending on lesion location: Figure 2 shows an example of a 54-year old patient with acute onset right-hemispheric stroke 6 hours earlier with lesion evolution in the right basal ganglia (upper row). While the lesion can be well detected on DWI (b=1000) and the corresponding ADC map, the boundaries are hard to appreciate due to similarity of the signal of the normal white matter and the acute ischemic lesion, both showing high scores for the probability of zero displacement. This problem can in part be overcome with different scaling as demonstrated in Figure 3. In the bottom row of figure 2 the images of a 42-year old woman with acute stroke due to underlying carotid artery disease are shown. In the cortex signal abnormalities due to acute stroke can be visualized more precisely due to strong contrast of normal gray matter and ischemic tissue.

DISCUSSION/CONCLUSIONS High b-value q-space analysis of diffusion MRI is sensitive to acute stroke lesions, that are not yet visible on T2-weighted MRI. Such lesions with reduced diffusion coefficients are commonly detected on DWI and ADC maps with b-values up to 1000 s/mm^2. A possible limitation of this technique in acute subcortical stroke is due to similar signal of areas of densely packed white matter (e.g. corpus callosum) and the acute ischemic lesion on the q-space derived maps, both being areas with prominent slow diffusion components. However cortical ischemic lesions can be demonstrated well because of the low probability for zero displacement in normal cortical tissue.

Figure 1

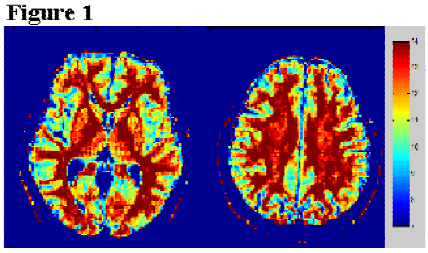

Figure 2

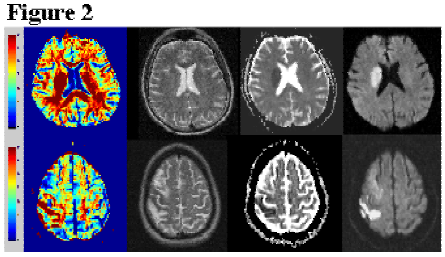

Figure 3