Change in Axial and Radial Diffusional Kurtoses for Ischemic Stroke

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Introduction

Diffusion-weighted imaging (DWI) is widely applied for the clinical assessment of ischemic stroke. Most notably, a drop in the Mean Diffusivity (MD) of roughly 50% typically occurs within the affected region [1]. For the same ischemic region, the Mean diffusional Kurtosis (MK), which is an indicator of diffusional heterogeneity, may also increase substantially [2-4]. In this study, we further investigated this phenomenon by measuring, in addition to the MD and MK, the axial and radial diffusional kurtoses in three patients with focal ischemic stroke.

Methods

The diffusional kurtoses were estimated by applying the DWI method of Diffusional Kurtosis Imaging (DKI) [5, 6] to scan three patients with subacute focal ischemic stroke confined to a single brain hemisphere. MRI scans were performed between 13 and 26 hours following the onset of symptoms. With DKI, we obtained parametric maps for the MK, axial kurtosis (Kax), and radial kurtosis (Krad). Kax is defined as the diffusional kurtosis in the direction parallel to the diffusion tensor eigenvector corresponding to the largest eigenvalue, while Krad is defined as the diffusional kurtosis averaged over all directions perpendicular to this eigenvector. Our definition for Kax corresponds to that of Hui et al. [7], but our definition for Krad is different. For one patient, three b-values were used (0, 1000, 2000 s/mm²), with the other imaging parameters being: # diffusion directions = 30, slice thickness = 5 mm, TE = 96 ms, TR = 4500 ms, and in-plane resolution = 2.6 mm × 2.6 mm. For the other two patients, six b-values were used (0, 500, 1000, 1500, 2000, 2500 s/mm²), with the other imaging parameters being: # diffusion directions = 30, slice thickness = 5 mm, TE = 104 ms, TR = 1500 ms, and in-plane resolution = 2 mm × 2 mm. All scans were performed on a Siemens 1.5T Avanto scanner. In addition to MK, Kax, and Krad, the DKI dataset was also used to calculate, as references, parametric maps for the MD, fractional anisotropy (FA), axial diffusivity (Dax), and radial diffusivity (Drad).

For each subject, a region of interest (ROI) was drawn on a single slice within the ischemic region, as identified on the MD maps, and a corresponding ROI of identical size was drawn on the contralateral side. For one patient, the ROI contained 36 voxels, while for the other two they contained 12 voxels. Values for each of the diffusion metrics were obtained by averaging the maps over the ROI, and “percent changes” were calculated from 100[(X(ischemic) – X(contralateral)]/X(contralateral), where X represents any of the diffusion metric values.

Results

Figure 1 shows diffusion metric values for the ischemic regions versus. values for the contralateral regions. For two patients, Kax showed little change (vertical arrows), although Krad changed substantially (horizontal arrows). The line of slope one is included as a visual reference.

Discussion

For this preliminary study, we observed a large change in Kax for all three patients, but Krad did not change substantially for two of these. The two patients with small Krad changes had high contralateral FA values (0.49 and 0.61), indicating regions comprised mostly of white matter. This suggests that, for white matter, ischemia increases diffusional heterogeneity primarily in the axial direction. This observation, if confirmed in studies with more subjects, may provide an important constraint on the various and still debated models of how ischemia alters diffusional properties in brain [8, 9]. For example, the large change in Kax may be related to ischemia-induced axonal varicosities [10].


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