

Fractional Anisotropy Changes of White matter Infarction and Hypoperfusion in Patients with Hyperacute Stroke: A Voxel-based Analysis Using DTI and DSC Perfusion

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Target audience: MR scientists, Neuroradiologists and Neurologists.

Background: The fractional anisotropy (FA) obtained from diffusion tensor imaging (DTI) may provide an additional means of differentiating the microstructural changes due to ischemic brain injury, particularly in white matter (WM) ¹. The FA changes are heterogeneous and variable between the infarction core and ischemic regions depending on the severity of ischemia and time of onset ².

Purpose: The purpose of this study was to evaluate the DTI-FA changes of white matter infarction and hypoperfusion in patients with acute ischemic stroke (AIS) using a quantitative voxel-based analysis.

Methods: The inclusion criteria for this prospective study were: patients with AIS who presented within 6 hours from symptom onset with acquisition of both DTI and DSC on a 3T MR scanner (Skyra, Siemens). DSC perfusion was performed using a gradient-EPI sequence (TR/TE: 1450/22 msec, FA 90°, FOV: 22×22-cm, matrix 128 mm, voxel size 1.7 x 1.7 x 4 mm³, GRAPPA x3) after intravenous injection of 0.1 mmol/kg of Multihance-gadolinium contrast. DTI were acquired by using single-shot echo-planar imaging (TR/TE, 5500/82 ms; FOV: 22×22-cm; matrix 128 mm; voxel size 1.5 x 1.5 x 2 mm). Diffusion-sensitized gradients were applied along 20 noncollinear directions with a b-value of 1000 s/mm² resulting in 4 minutes acquisition time. The measured FA, apparent diffusion coefficient (ADC), and Tmax images were coregistered for voxel-based quantification using a region-of-interest (ROI) approach in the ipsilateral affected side and in the homologous contralateral WM. The infarction core and hypoperfusion were determined by threshold method defined as an ADC value less than 600 x 10⁻⁶ mm²/s ³ and DSC-Tmax > 2 sec ⁴. A mask of the gray matter (FA threshold > 0.15) was generated for each patient to ensure extraction of voxel values is limited only to WM. The image analysis was performed by combination of FDA approved software (Olea Medical, La Ciotat, France) and Matlab. Data were analyzed by unpaired t-test.

Results: Fifteen patients (9M, age 48-83y/o) met our inclusion criteria. The average time from onset to MR imaging was 4.3 hours and the NIH stroke scale range was 4-12. Total number of voxels included were 1100 for WM infarction, 5100 for WM hypoperfusion and 3300 for normal contralateral WM. The mean of FA values was significantly higher in the regions of WM hypoperfusion (p<0.0001, t: 7.90) and significantly lower in the regions of WM infarction (p<0.0001, t: 6.52), compared to FA values in the contralateral normal WM. The mean of Tmax values was significantly higher in both WM hypoperfusion (p<0.0001, t: 58.31) and WM infarction (p<0.0001, t: 42.70), compared to Tmax values in the contralateral normal WM. The mean ADC values was significantly lower in the WM infarction (p<0.0001, t: 58.3) in comparison to hypoperfused WM and normal WM. There was no statistically significant difference between the mean ADC values in the WM hypoperfusion and normal WM (p = 0.07, t: 2.1). The FA values were significantly higher (p<0.0001, t: 32.0) in the hypoperfused WM with Tmax ≥ 6 in comparison to regions with Tmax < 6 sec with a mean difference of 0.14.

Discussion: Reduced DTI-FA values in the WM infarction may signify the loss of cellular integrity with irreversible cellular injury as reported previously ¹. DTI-FA can also identify ischemic changes in the hypoperfused WM. In WM with Tmax ≥ 6 sec, increased anisotropic diffusion likely represents microstructural changes that result in fluid shift from the extracellular to intracellular space without cell membrane disruption ⁵.

Conclusion: DTI-FA is decreased in regions of WM infarction and increased in hypoperfused WM in patients with AIS. The FA values are significantly higher in the hypoperfused WM with Tmax ≥ 6 sec suggestive of early microstructural changes related to ischemia.

References:

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