High b-value diffusion tensor imaging of remote white matter and the white matter of obstructive unilateral cerebral arterial regions

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Purpose

DTI with conventional b values (#1000 s/mm²) has been used to depict brain abnormalities in ischemic diseases. However, the sensitivity of DTI with conventional b values is limited in evaluating the diffusion changes in normal-appearing white matter (NAWM) in patients with cerebral arterial severe stenosis or occlusion. This technique only shows diffusion abnormalities that coexist with magnetic resonance imaging (MRI)-evidenced T2-weighted diffusion hyperintensity or secondary neuronal degeneration after stroke. Several studies have demonstrated that DTI with high b values (#1900 s/mm²) is more sensitive than that with conventional b values in detecting occult parenchymal changes in chronic ischemia or suspected brain infarction. The purpose of this study was to use DTI with a high b-value (2200 s/mm²) to assess the diffusion changes in NAWM in patients with unilateral, severe stenosis or occlusion of the middle cerebral artery (MCA).
Methods and Materials

We investigated 34 consecutive patients (12 women; mean age 49±11 years [range 28-65 years]) with unilateral, severe stenosis (#75% diameter reduction) or occlusion of the M1 segment of the middle cerebral artery (MCA) as seen on magnetic resonance angiogram (MRA).

MRA revealed normal contralateral MCA and bilateral anterior and posterior cerebral arteries. MRI with DWI and DTI involved the use of a 3.0-T MR scanner. For all brain imaging, a quadrature birdcage head coil was used. The scanning protocol was contiguous 3-mm-thick sagittal T2WI, contiguous 5-mm-thick axial T2WI (TR, 4600 ms; TE, 102 ms; NEX, 2) and T1WI with a spin-echo pulse sequence (TR, 550 ms; TE, 9 ms; NEX, 2); axial T2WI/FLAIR (TR, 7500 ms; TE, 120 ms; NEX, 2) and axial DWI (TR, 5000 ms; TE, 66.5 ms; NEX, 4; b=1000 s/mm²) with echo-planar and 3D-TOF-MRA (TR, 3.2 ms; TE, 22.5 ms; NEX, 1), then axial sensitivity encoded echoplanar DTI with conventional and high b value (TR, 6000 ms; TE, 90 ms; NEX, 4; 5 mm of thickness was used to match the thickness of axial MRI; 15 noncollinear gradient directions; b=2200 s/mm² determined by a preliminary study).

FA, ADC and eigenvalues (#1, and #23 corresponding to the axial and radial diffusion, respectively) were measured at the ipsilateral (hemisphere affected by the stenosed or occluded MCA) and contralateral (hemisphere unaffected by the normal MCA) corona radiata, anterior and posterior limb of internal capsule, cerebral peduncle and pons for all patients. ROIs were symmetrically drawn manually with a mirror method.

Data analysis was conducted using SPSS 13.0 (SPSS Inc., Chicago, IL, USA). Paired t tests were used to compare mean FA, ADC, #1 and #23 values of the ipsilateral and contralateral corona radiata, anterior and posterior limbs of the internal capsule, cerebral peduncle and pons used as a control with a b value of 2200 s/mm². p < 0.05 was considered statistically significant.
Results

MRA revealed stenosis (#75% diameter reduction) or occlusion in the right M1 segment of the MCA in 18 patients (53%) and in the left M1 segment in 16 patients (47%). These patients showed few or absent distal branches in ipsilateral MCA. MRA revealed a normal contralateral MCA and bilateral anterior as well as posterior cerebral arteries in all patients.

The mean FA was significantly lower at the ipsilateral corona radiata and anterior and posterior limbs of the internal capsule than at the contralateral corona radiata and anterior and posterior limbs of the internal capsule (p<0.05). The mean ADC, #1 and #23 were significantly higher at the ipsilateral corona radiata than at the contralateral corona radiata (p<0.01). The mean #23 were significantly higher at the ipsilateral anterior and posterior limb of the internal capsule than at the contralateral anterior and posterior limbs of the internal capsule (p<0.05). Mean FA, ADC, #1 and #23 were not significantly different between the bilateral cerebral peduncle and pons (p>0.05; Figs 1).

Maps of FA, ADC, #1 and #23 with b value of 2200 s/mm2 of a patients with NAWM and unilateral, severe stenosis or occlusion of the middle cerebral artery were shown in Figs. 2 to 4.
Fig. 1: Graph 1 Comparison of fractional anisotropy (FA), apparent diffusion coefficient (ADC), axial diffusivity (eigenvalue #1) and radial diffusivity (eigenvalue #23) with b values of 2200 s/mm² between the bilateral corona radiata, anterior and posterior limbs of the internal capsule, cerebral peduncle and pons in unilateral middle cerebral artery occlusive disease. (Note: ICR and CCR refer to the ipsilateral and contralateral corona radiata, respectively. IALIC and CALIC refer to the ipsilateral and contralateral anterior limbs of the internal capsule, respectively. ICPE and CCPE refer to the ipsilateral and contralateral cerebral peduncle, respectively. ICPO and CCPO refer to the ipsilateral and contralateral cerebral pons, respectively. All terms are in relation to unilateral middle cerebral artery occlusive disease.)

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Fig. 2: Fig. 2. Fractional anisotropy (FA), apparent diffusion coefficient (ADC) and eigenvector maps of the corona radiata. (A) The FA map indicates decreased anisotropy in the green region of the ipsilateral corona radiata (arrow). (B) The ADC map indicates increased diffusive magnitude in the blue region of the ipsilateral corona radiata (arrow). (C) The axial diffusivity eigenvector map indicates increased parallel diffusive magnitudes in the light blue regions of the ipsilateral corona radiata (arrow). (D) The radial diffusivity eigenvector map indicates increased perpendicular diffusive magnitudes in the light blue regions of the ipsilateral corona radiata (arrow).

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Fig. 3: FA, ADC and eigenvector maps of the anterior and posterior limbs of the internal capsule. (A) The FA map indicates decreased anisotrophy in the light red region of the ipsilateral anterior and posterior limbs of the internal capsule (arrow). (B) ADC and (C) axial diffusivity eigenvector maps indicate similar parallel diffusive magnitudes at the bilateral anterior and posterior limbs of the internal capsule. (D) The radial diffusivity eigenvector map indicates increased perpendicular diffusive magnitude in the light blue regions at the ipsilateral anterior and posterior limbs of the internal capsule (arrow).

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Fig. 4: FA, ADC and eigenvector maps of the pons. (A) The FA, (B) ADC, (C) axial diffusivity eigenvector and (D) radial diffusivity eigenvector maps indicate similar diffusive magnitudes at the bilateral pons.

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Conclusion

High b-value DTI may be used to sensitively depict diffusion changes in the white matter of obstructive cerebral artery regions without abnormal anisotrophy and diffusivity in the remote cerebral white matter in patients with severe MCA stenosis or occlusion without MRI evidence of brain parenchymal abnormalities.
References


