Assessment of early diffusion changes in Wallerian degeneration with three-dimensional fiber tractography

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Introduction Three-dimensional diffusion tensor fiber tractography (3D-DTT) is based on eigenvalues and eigenvectors derived from diffusion tensor matrices. It allows us to calculate rotationally invariant indices defined by eigenvalues including fractional anisotropy (FA) and apparent diffusion coefficient (ADC) of a tract. Wallerian degeneration of ischemic stroke causes diffusion abnormalities in axons distant from an infarction along a particular neuronal pathway. Quantification of diffusivity seems helpful in assessing progress of the degeneration [1, 2]. Our purpose was to quantify FA and ADC along corticospinal tract (CST) using a 3D-DTT technique in order to reveal early diffusion changes caused by Wallerian degeneration in stroke patients.

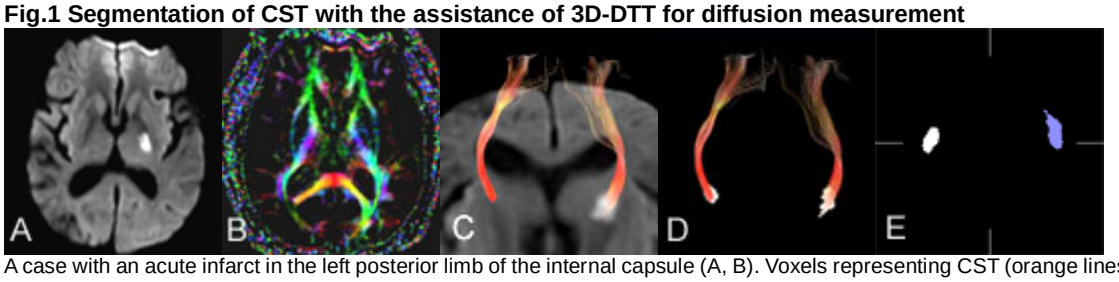
Materials and Methods Eligible patients were:1) with an acute or subacute infarct that was clinically relevant to a motor deficit, 2) with the infarct that was shown involving CST on 3D-DTT and 3)without hemorrhage within or around the infarct. 10 patients who had fulfilled the criteria were enrolled (1 to 10 days after stroke onset). We used a 1.5-T Signa imager (GE, Milwaukee, Wis) and obtained 30-34 interleaved, 5mm thick, gapless images to cover an entire brain (TR/TE=5000-6000/76.8-102, NEX 2, FOV 24.0cm, matrix 128×128, 13 non-collinear gradient axes with b=1000 as the peak gradient). 3D-DTT of CST was obtained using free software (VOLUME-ONE and dTV [3]) without setting stop criteria for FA or ADC, and was then converted to binary images to perform segmentation of voxels representing the CST (Fig.1). Thus we measured mean FA and mean ADC values of CST within the infarct (designated as 0cm in parenthesis in the following sentences) and similarly in a location 3cm inferior to the infarct (i.e. -3cm) to 3 cm superior to it (i.e. +3 cm) at 1cm intervals along the course of CST. We calculated the ratio of FA values (and ADC values) to those of the matching location of the contralateral healthy CST, and relative values were plotted against time from onset of stroke.

Results Relative value analyses suggested that FA (+1cm) decreased earlier than FA(-1cm) in 6 to 10 days after stroke onset, whereas ADC(+1cm) and ADC(-1cm) showed a minimal decreasing trend even 10 days after onset (Fig.2). No specific trend in diffusion changes was observed in locations that were more than 1cm distant from the infarct.

Discussion and Conclusion FA and ADC values of CST could be selectively measured with the assistance of 3D-DTT. Segmentation of CST ensures us measurement precisely in it. This technique encourages us to unravel secondary degeneration derived from various diseases by way of a particular neuronal pathway including Wallerian degeneration. Our results suggest that diffusion anisotropy might decrease at the initial stage of Wallerian degeneration while isotropic diffusion remains normal and that the degeneration might advance in ascending fashion, or toward nerve cell bodies, more rapidly. In conclusion, 3D-DTT seems useful in detecting and evaluating early diffusion changes of CST caused by Wallerian degeneration in stroke patients.

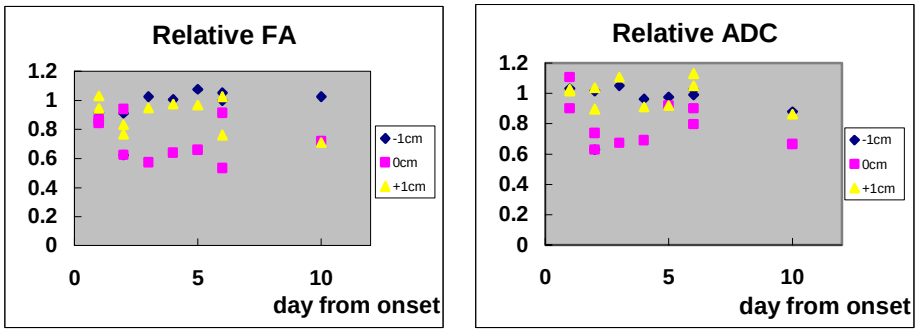
References [1] Pierpaoli C, et al. Neuroimage. 2001 13:1174-85 [2] Mazumdar A, et al. AJNR Am J Neuroradiol. 2003 24:1057-66 [3]VOLUME-ONE: available at *http://www.volume-one.org*

Fig.1 Segmentation of CST with the assistance of 3D-DTT for diffusion measurement



A case with an acute infarct in the left posterior limb of the internal capsule (A, B). Voxels representing CST (orange lines) are segmented, colored white (C, D), and then used as a region-of-interest of CST(E).

Fig.2 Time- and distance-dependent changes of relative FA and relative ADC of CST



Notes: -1cm = 1cm inferior to the infarct, 0cm = within the infarct, +1cm = 1cm superior to the infarct