Increase of fractional anisotropy in contralateral thalamic motor nucleus in MCA stroke using tract-based segmentation method

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Introduction:

The vascular territory of middle cerebral artery (MCA) involves neo-cortices that govern high cortical functions including motor, sensory, language and skills. Occlusion of MCA can cause disruption of basal-ganglia-thalamocortical pathway [1] in which thalamus plays a pivot role in the process of rebuilding the circuitry after MCA stroke by neuro-adaptation called plasticity. [2] It is therefore important to establish non-invasive tool to assess the microstructural changes of thalamus in stroke patients. One previous study has demonstrated that, by using diffusion tensor imaging (DTI), an increase in mean diffusivity in thalamus was shown after MCA infarct but fractional anisotropy (FA) remained unchanged. This study was limited by a lack of investigating the individual thalamic nucleus [3]. Specifically, thalamic nuclei, including ventral anterior nucleus (VA), ventral lateral nucleus (VL) and ventral posterior nucleus (VPL) are known to play critical role in modulation and coordination of motor and sensory function. In this study, we aim to evaluate the changes of FA in these three motor-sensory-related thalamic nuclei in patients with MCA ischemic stroke at both acute and chronic stages using tract-based segmentation method.

Materials and Methods:

5 MCA stroke patients (4 men, 1 woman, and aged 62±14) and 10 normal controls (age- and gender matched) were enrolled in this study. Examinations of patients are arranged at seven days and three months after stroke onset, respectively. MR diffusion tensor imaging (DTI) was applied on a 3.0T scanner (Discovery MR750; GE Healthcare, Milwaukee, WI, USA) with 8-channel phased-array head coil. The data acquisition parameters were as follows: TR=8000 ms; TE=minimal TE; flip angle=90°; b values=0, 1000 seconds/mm^2; diffusion directions=40; FOV=240; matrix size=128×128 (zero-filled to 256×256); section thickness=4 mm; section gap=0 mm; Asset=2; total acquisition time of the DTI sequence=5:36 min. Images were registered first to the B_0 image by using affine registration to minimize the eddy current-induced distortion. After data acquisition, fiber-tracking was performed using MRtrix software package (Brain Research Institute, Melbourne, Australia, http://www.brain.org.au/software/) based on probabilistic streamlines method. As to the segmentation of the motor-related nuclei, the indirect differentiation method proposed by Yamada et al. [4] was performed using two deterministic seeds for propagation of fibers: one was placed at the ventral thalamus (motor) and medial lemniscus (sensory), respectively, and the other was placed at the premotor cortex including the supplementary motor area, primary motor cortex, and primary sensorimotor cortices, respectively (Fig. 1(1)).

Results:

Fig. 1(2) showed the results of the tract-based segmentation in motor-related thalamic nuclei, in which identification of the VA, VL as well as VPL was improved. In addition, evaluation of FA values in the bilateral VA, VL and VPL were presented in Fig 2. There are no significant differences of FA in ipsilateral side at acute stage (P = .11, .11 and .69 for VA, VL and VPL, respectively) and chronic stage (P = .42, .11 and .23 for VA, VL and VPL, respectively). However, patients with MCA stroke had significantly increased FA in contralateral VL (P = .03) than control at acute stage. No significant changes of FA were shown for VA and VPL at acute stage (P = .12 and .27 for VA and VPL, respectively), and VA, VL and VPL at chronic phase (P = .40, 0.45 and .69 for VA, VL and VPL, respectively).

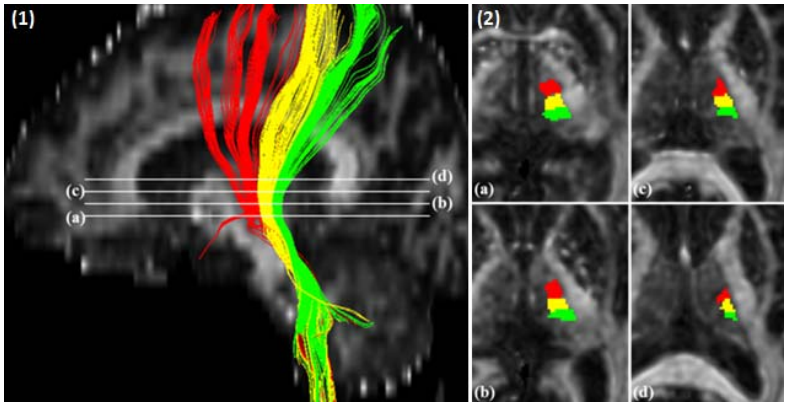

Figure 1 (1) Demonstration of fiber tracts derived from DTI model. (2) segmentation of the VA (red), VL(yellow), and VPL(green) were shown in four contiguous slices, respectively.

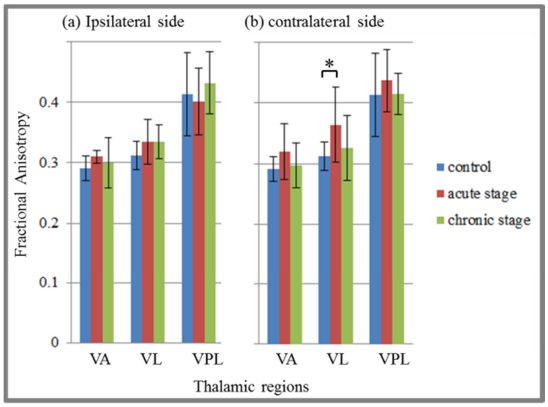

Figure 2 Statistical results of FA measurements in the ipsilateral (a) and contralateral (b) VA, VL, and VPL, respectively.

Discussion:

To our best knowledge, this is the first study to examine and follow-up in vivo the microstructural changes of motor-sensory-related thalamic nuclei using FA measurements in patients with MCA stroke. Previous studies have demonstrated that supplemental recruitment of contralateral cortical areas may occur after ischemic stroke [5]. In our preliminary result, significant increase of FA in VL was observed in MCA stroke patient at acute stage, suggesting the important role of VL in modulation and coordination of the motor function during acute period. This is also in concert with the concept of early rehabilitation intervention for motor improvement in acute stroke patient. In conclusion, tract-based tracking method allows improved localization of motor-sensory-related thalamic nuclei and this further provides non-invasive evaluation of the microstructural changes of thalamus after MCA stroke, which may have potential in making therapeutic strategy in stroke patients.

Reference:

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