Dynamic changes of the pyramidal tract after ischemic stroke detected by MR axonal diffusion tractography

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INTRODUCTION:

The integrity and connectivity of nerve fiber tracts in the brain are important in assessing plastic changes related to functional recovery and to obtain prognostic information and formulate future therapeutic strategies for stroke patients. The few studies with diffusion tensor axonal fiber tracking, diffusion anisotropy measures and functional imaging, demonstrate that the adult brain after ischemia has the potential to regenerate and compensate for motor deficits by a variety of plastic changes, including an initial recruitment of motor pathways in the intact hemisphere, and in patients with good recovery, return of activity to the ipsilesional side (1-6). To our knowledge, the spatial reorganization of fiber tracts in a longitudinal study of stroke from the onset of the acute stroke and throughout rehabilitation has never previously been documented in humans. The aim of the study was to test whether the density ratio (measured as number of tracked fibres per unit volume) of the pyramidal tract fibres between the ipsi- and contra-lesional side reflects regeneration of pathways during rehabilitation and correlates with motor function. We hypothesized that an increase in fiber density bilaterally is associated with good recovery and conversely that sustained low density-ratio due to reduced density of the affected side is associated with poor outcome. The relationship between plastic changes of the fiber bundles in white matter following ischemic stroke and motor recovery was investigated by spatially resolved diffusion measurements (DTI) and computer based 3D axonal fiber tracking algorithms correlated with neurological motor scales.

METHODS:

Four right-handed first-time stroke patients with ischemic infarcts located in the area of internal capsule or corona radiata were examined in the acute phase (range 2-5 days), after one and three months post-stroke and functionally tested with Medical Research Council (MRC) scale, Motor Assessment Scale, Scandinavian Stroke Scale, Berg´s Balance Scale and Barthel`s Index. DTI was performed using a birdcage headcoil and double spin echo single shot EPI at 1.5 T. The diffusion encoding scheme consisted of 17 different directions isotropically distributed in space, b-factor of 1000 s/mm2. In addition, two b-factor=0 s/mm2 images were acquired. The maximum gradient strength was kept at 36 mT/m. 50 slices locations of slice thickness 3.3 mm were acquired, covering a 24 cm FOV in a 128 by 128 matrix. TR/TE =17000/84 ms. A total of 4 replicated scans were performed, acquisition time was 22 minutes. T1-weighted 3D imaging was also performed. After image co-registration the eigensystem was calculated from the diffusion tensor in each voxel using diagonalization. The principal eigenvector is assumed to represent the local direction of an axonal fiber and fiber tracking was performed by the FACT algorithm (7).

RESULTS:

Figure 1

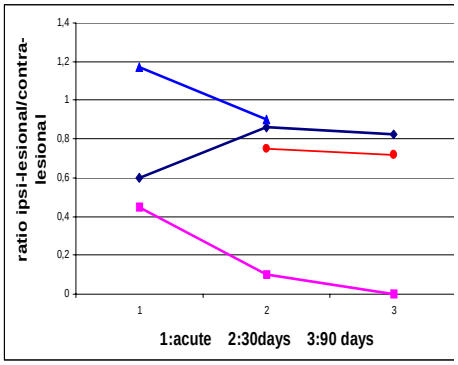


Figure 2

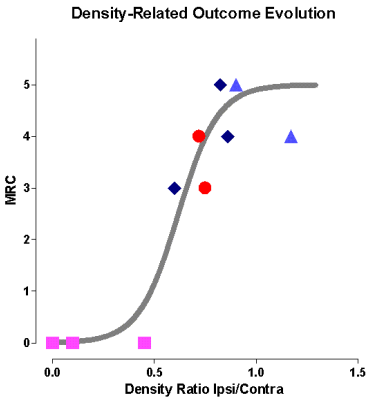
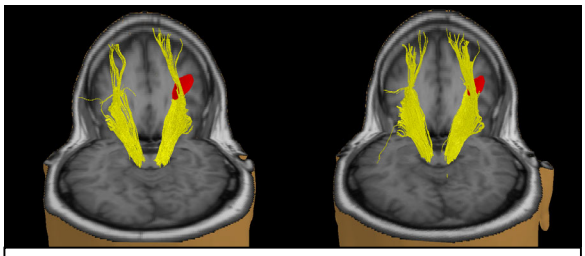


Figure 3



Pyramidal tracts acute (left) and after 3 months recovery (right) in a patient with good recovery (MRC>4). Infarct in right hemisphere (red). (Posterior view)

The temporal evolution of the density ratio in relation to motor function (MRC) is shown in Figures 1 and 2, respectively (acute DTI data for one patient was discarded due to data errors and one patients follow-up (90 days) has not yet been obtained). An initially low or decreasing density ratio is associated with low values of MRC, leading to poor outcome, and, the high or increasing ratio, to good outcome. The fiber density in the pyramidal tract of the ipsi-lesional hemisphere increased in the two patients with good outcome (MRC=5), and an increase in fiber density on the contra-lesional side, particularly in the 0-30 day phase, was associated with better outcome (not shown).

DISCUSSION:

The novel finding of fiber density related progression of outcome from ischemic stroke is based on preliminary data and more studies are needed to validate the method and confirm the finding. Nevertheless, this longitudinal study is a promising and sensitive tool of assessment of the plastic changes within motor pathways in correlation to motor function during recovery from stroke.

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