Automatic segmentation of the pyramidal tract basing on whole-brain DTI imaging

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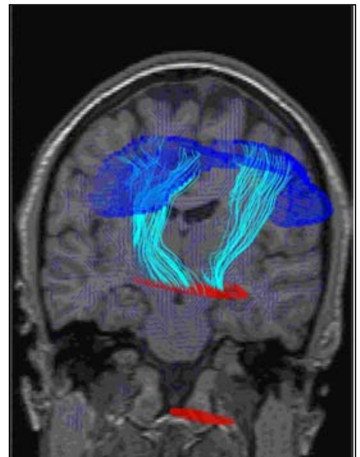
Introduction:

Using diffusion tensor imaging (DTI), the non-invasive evaluation of large fiber tracts including the pyramidal tract has become possible. A segmentation of the pyramidal tract is expected to improve neuro-navigation. The pyramidal tract can also be used as landmark when positioning deep brain stimulation electrodes. The advantages of an automatic segmentation tool are less personal effort, independence of the examiner and faster availability of the results. Yet experienced personnel has to check the results.

Methods:

We investigated 10 healthy male right handed subjects (mean age 28 years (26-33)) using the same imaging parameters for diffusion tensor imaging. A written informed consent was obtained from all individuals before the investigation. Imaging was performed on a 1.5T scanner (Philips Intera, Best, The Netherlands) using a standard headcoil. After a whole head thin sectioned T1 weighted gradient echo sequence, diffusion weighted images were obtained employing a pulse-triggered diffusion weighted multishot spin-echo EPI sequence with two b values (0 s/mm2 , 1000 s/mm2) along each of nine different gradient axes with the following parameters: Repetition time (TR): 1 beat, Echo Time (TE): 22ms, Flip angle (FA): 90° , field of view (FOV): 200x200 mm, Matrix: 128x128, slice thickness: 2mm, no interslice gap. Depending from the pulsefrequency of the subject the total acquisition time was about one hour.



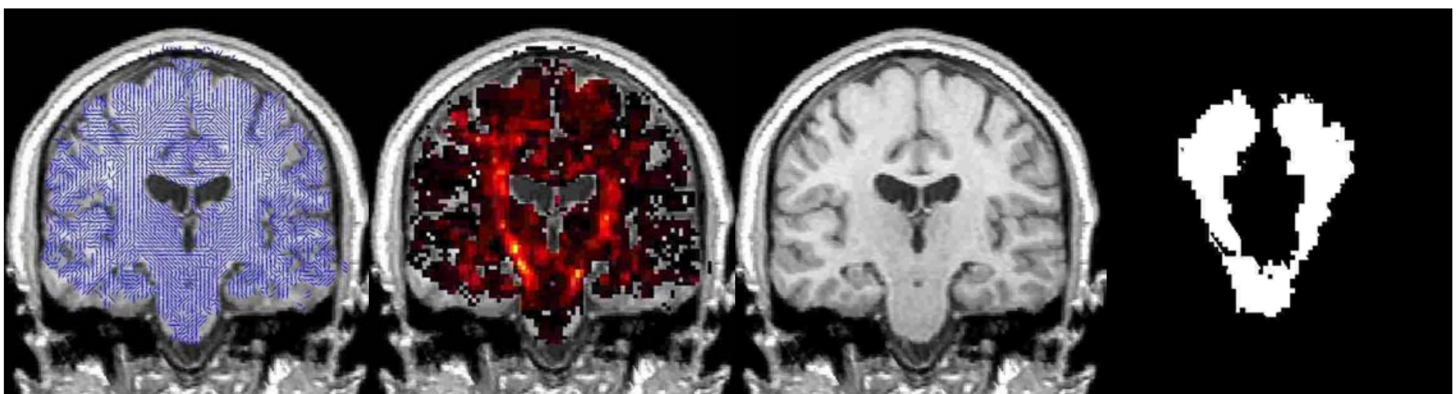
Visualization of tracked fibers that connect the peduncel cerebri to Brodmann area 4 as used in the first method.

All DTI images were reoriented to the magnet coordinate system with iso-voxels of 2mm. After computation of the ADC map, the components of the tensor (eigenvectors and eigenvalues) were computed in a least squares approach. Measuring 9 different gradient axes the symmetric diffusion tensor with 6 degrees of freedom was overdetermined. By this approach the tensor with minimimal squared errors was choosen. After this procedure, the anisotropy map and the principal eigenvector map were available.

Two different methods of a segmentation of the pyramidal tract were examined. The first method used line propagation and selected those paths who connected the peduncel cerebri to Brodmann area 4, which was defined in MNI-space and transformed to the individual space by rigid body transformation. This transform was computed from the T1 weighted gradient echo scan and the software package SPM2 (Wellcome Department, London, UK). The fiber tracking was calculated on the main directions after application of a simple three-dimensional Gaussian filter with a FWHM of 0.75 voxels. Fiber tracking stopped if a T1 treashold was exceeded or the relative anisotropy was less than 0.2. All voxels crossed by the selected fibers were included in the segmentation.

The second method was voxel based and chose the voxels according to direction of the main diffusion component, the anisotropy and T1-intensity comparing them to expected values dependent on the localization in a fuzzy logic approach.

After transformation to the MNI-space using rigid body transformations the results for every method were compared to a probability map (p>.5) from a histological study that examined different subjects. The mean distance of the mismatch voxels the next matching voxel was calculated. Additional a probability map for each method was calculated and correlated to the histological probability map.



The voxel based method used the local main fiber direction, the anisotropy and T1 intensity for segmentation. The resulting segmentation is shown in black and white.

Results:

The mean mismatch distance were 3.70552+-0.15714mm for the first method and 3.0031+-0.20737mm for the second method . The correlation coefficient of 0.576831 was found for first method. The correlation coefficient for the second method was 0.624945. Suszeptibility artefacts near to the mastiod compromised the image quality and therewith the results slightly.

Conclusion:

Automatic segmentations of the pyramidal tract reflect histological findings. The voxel based method so far shows least mean errors as compared to a standard based on histological segmentation for normal subjects. Line propagation methods nevertheless are expected to be more efficient in a disturbed anatomy. Since only the main fiber direction can be determined in each voxel, errors adding up yield a more strikt criterion for voxels to be segmented. If the pyramidal tract has been displaced by a mass, still an estimation of the relative situation of the tract may be possible. Both methods can also be applied for other large fiber tracts.