High spatial resolution probabilistic DT fibre tracking using seeding points from fMRI statistical parameter maps

G. Vucurevic[1]

[1]Institute of Neuroradiology, University Hospital Mainz, Mainz, Germany

Introduction: Determining the direction of the highest water diffusion anisotropy is commonly used for white matter fibre tracking. Two main obstacles: 1) low spatial resolution that causes overlapping of the signal from fibres with different orientation and 2) low signal to noise of the diffusion measurements could be resolved using measurements with more gradient orientations for higher angular resolution of diffusivity and more sophisticated models than 2-rank tensor model. However, direction of single fibre tracts is well determined with the direction of main eigenvector obtained from water diffusion tensor model, which implies that instead of using high angular resolution, high spatial resolution DTI with adequate S/N is, if possible, is more straightforward alternative. Probabilistic fibre tracking approach is the only that offers the error estimate of parameters and gives realistic representation of white matter fibre connections in the brain. We exploited parallel acquisition technique to gain spatial resolution and reduce EPI sequence high susceptibility artefacts by reducing the number of phase encoding steps.

Material and methods: EPI sequence with 12 diffusion gradient directions was used (TR=13600 ms, TE=101 ms, 1x1x2 mm space resolution 256x256 matrix with 64 slices, 1 acquisition 4min 18 sec).15 successive acquisitions were collected in 23 year old right handed healthy female volunteer. Measurement was made in 1.5T scanner with 8 channel head coil using GRAPPA acquisition and reconstruction technique with acceleration gain factor of 2. In separate measurement with the same subject T1– MPRAGE 3D structural data set was made and two fMRI tasks: finger tapping task and speech task (simple sentence generation, -"xx is a bird/mammal" after presenting picture). Both tasks were in block design of 10 scans of "active" condition against 10 scans of baseline condition.(EPI sequence with TR=3.2 sec/TR=4.5 sec; TE=60ms, FOV=192 mm, space resolution of 3x3x5 mm. Additionally DTI scan using 6 gradient scheme (b=0&b=1000) was performed using 10 acquisitions. Postprocessing: fMRI analysis was performed using SPM2 software (http://www.fil.ion.ucl.ac.uk/spm). Image volumes were realigned and smoothed (smoothing Gaussian kernel of 6x6x8 mm) statistical parameter maps were created using design matrix according to block design mentioned above. t=7 as a threshold for "statistical significant" activation. Active regions were used as seeding masks for DTI fibre tracking.15 diffusion datasets were motion corrected using SPM realignment procedure. Mean image was made for each of different diffusion gradient images (using realignment parameters from b=0 images), and a single dataset of size of 110 MB was created. DTI analysis was made using FDT tool of FSL software[1](processing time of 24 hour analysis on 3GHz Pentium4 processor Linux PC with 2GB memory). Probability distribution functions for angles of eigenvectors were estimated and data set was ready for probabilistic fiber tracking. Seeding areas were selected from BOLD activation maps. Regions of interest were coregistered to b0 image of DTI datasets.

Results:
After realignment we used averaged image volumes as new dataset. Memory constraints (2 GB RAM) were limitation factor for using all 15 datasets separately. With realignment&averaging procedure it was possible to preserve high resolution of individual measurements, although subject motion during 1h30 min scanning time was more than 5 mm. Coregistration of BOLD activation areas obtained from motor task and pyramidal tract reconstructed by fibre tracking have shown also presence of BOLD activation along the dense fibre tracts (superior to capsula interna) and in the pons and lower portions of the brainstem. Branching of the tract going from primary motor area to the capsula interna and putamen (extrapyramidal branch) was also demonstrated. BOLD activation was present both in both putamina and thalami for the motor task. As illustration of fibre tracking results two examples are shown on Fig 1(left) and Fig 2(right)

Figure 1 demonstrates optic pathways seen with this method. It was possible to track visual pathway from primary visual cortex to lateral geniculate body and further to optic chiasm. Taking the seeding points in optic chiasm, fibre tract was going to the lateral geniculate body and further to optic radiation into the primary visual cortex. The small tract branching to superior colliculus is also detected, as well as fibres that go directly to the hypothalamus. Using lower resolution DTI scans branching to optic chiasm and pathway to superior colliculus were not detected.

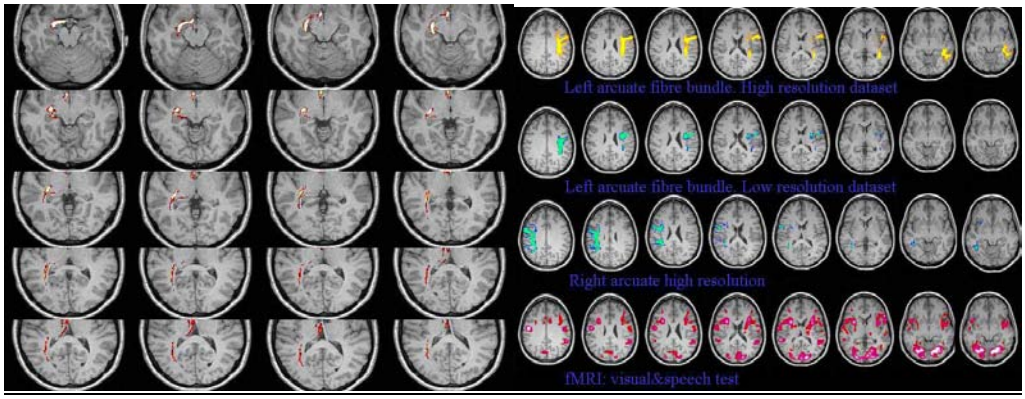

Figure 2. Arcuate fibers. With both "high" and low resolution it was possible to find approximately same volume of fibers in the portion of the tract towards the Broca area. Fibre crossings in region adjacent to optic radiation in low resolution measurements did not allowed tracking further to the Wernicke area. Only on the high resolution dataset fibres that come from the Wernicke area were possible to track.. We found high asymmetry in amount of fibres in the proximity of Wernicke area, giving substantially larger fibre volume on left side in comparison to the right side.

Consclusion: Higher spatial resolution DTI enabled substantially improved fibre tracking. We were able also to demonstrate presence of BOLD activation along the fibre tracts that are highly involved in signal processing for the given task.. Lower energy demand for the signal transmission in white matter does not restrict appearance of BOLD activation given high S/N measurements.

Literature:

[1]Behrens TEJ et al.:Characterization and propagation of uncertainty in diffusion-weighted MR imaging.,*Magn Reson Med*, 50(5):1077-1088, Nov 2003