Anatomically Reliable DTI-Tractography based on DW-STEAM

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Introduction:

Typical implementations of diffusion tensor imaging protocols available at clinical sites are based on echo-planar-imaging (EPI) and consequently subject to geometric artifacts. Even though a range of correction methods have been proposed for post processing, it would be advantageous to exclude corresponding errors at the acquisition level. Parallel imaging techniques in combination with EPI have been used to this effect [1] but some residual artifacts remain. In contrast, MRI sequences with RF-refocused echoes are inherently immune to susceptibility-induced distortion. Based on this premise a diffusion-weighted single-shot STEAM sequence [2] is shown to produce high-quality images without sacrificing anatomical correctness. As an ultimate test of geometric fidelity, fiber tracks have been calculated, some of them extending to regions poorly accessible to gradient echo sequences because of pronounced susceptibility differences.

Methods:

Diffusion-weighted images (38 slices; b=0,1000 s/mm^2) were acquired at 2x2x2mm^3 isotropic resolution in healthy volunteers using single-shot STEAM and 5/8 partial Fourier encoding in combination with the POCS reconstruction algorithm. The protocol comprised 24 diffusion gradient directions aligned with the faces of two rotated dodecahedrons. Averaging each image four times the total measurement time amounted to 29 minutes. The raw images were interpolated to 1x1x1mm^3 resolution and smoothed with a Gaussian filter. Having estimated the diffusion tensors with SVD-based linear regression, the FACT fiber tracking algorithm was applied. Each voxel in the manually drawn ROIs contained 9 starting points. ROIs were defined on the color-coded MDD maps and chosen to lie orthogonal to the presumed fiber direction guided by an anatomical atlas. When necessary to discern between entangled white matter tracts, ROI-to-ROI tracking was employed. Stopping criteria included an anisotropy and a stiffness threshold.

Results and Discussion:

Figures A-C display fiber tracts from a single female subject overlaid on anatomical reference scans.

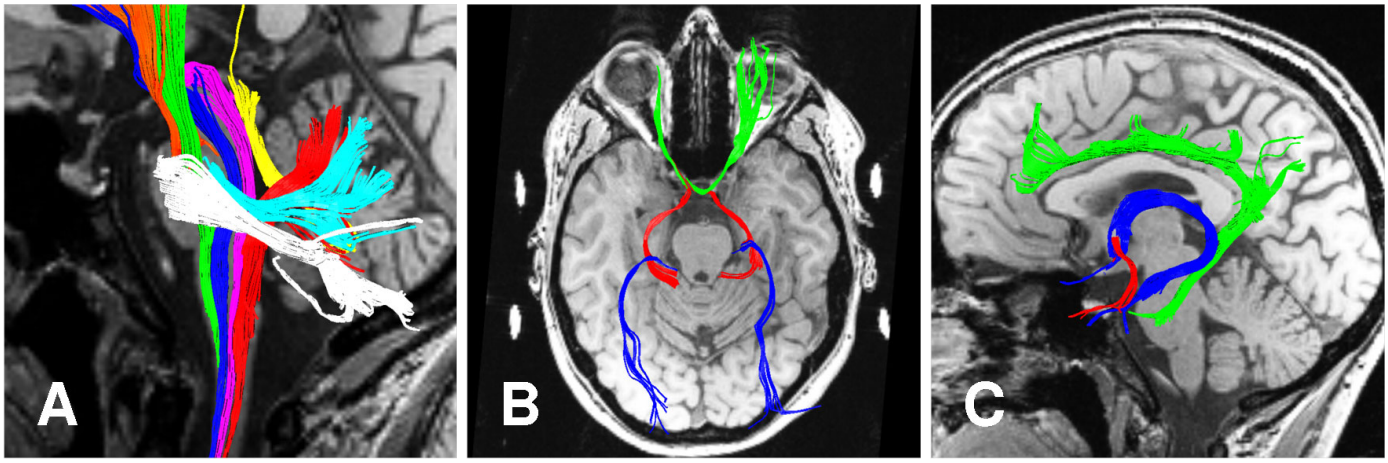

Figure A) Brainstem: corticopontine tract (orange), corticospinal tract (green), medial lemniscus (blue), medial longitudinal fasciculus (mauve), inferior cerebellar peduncle (red), superior cerebellar peduncle (yellow), middle cerebellar peduncle (ventral part: white; medial part: turquoise)
Figure B) Visual system: optic nerve (green), optic tract (red), optic radiation (blue)
Figure C) Limbic system: cingulum (green), fornix (blue), anterior commisure (red)

The computed tracks indicate that for the purposes of fiber visualization the STEAM sequence produces results on par with previously published work based on EPI [3,4]. Extending these capabilities, the approach presented here allows for reliable tractography even in sensitive regions like the brainstem and the anterior part of the visual system where gradient-echo acquisitions are impaired by signal loss or geometric distortions. The disadvantages of the current STEAM implementation with respect to acquisition time and SNR will be partially mitigated in future versions with the aid of parallel imaging techniques.

References:

[1] Jaermann et al. *MRM* **51**, 230-236 (2004); [2] Rieseberg and Frahm *Proc. ISMRM* 1185 (2004); [3] Catani et al. *NeuroImage* **17**, 77-94 (2002); [4] Stieltjes et al. *NeuroImage* **14**, 723-735 (2001).