Simultaneous High Resolution Ex-vivo Diffusion Imaging of White Matter and Muscles

T. Benner[1], A. Stevens[1], M. Roy[1], and B. Fischl[1]
[1]Radiology, Athinoula A. Martinos Center, Charlestown, MA, United States

Introduction

Diffusion-weighted imaging of fetal brain samples requires high spatial resolution given the small size of the samples. 2D single-shot echo-planar imaging (EPI) is not well suited for this purpose because of the limits in achievable slice thickness and in-plane resolution. 3D multi-shot EPI allows imaging with thinner slices and higher in-plane resolution, however, it is limited by the long repetition time required for T1 relaxation from shot to shot. In contrast, diffusion-weighted steady state free precession (DW-SSFP) imaging allows imaging at high spatial resolutions of 1 mm^3 or higher without these limitations [1-3]. In addition to white matter fiber tracking, diffusion imaging can also be used to depict muscle tissue [4-9]. In this study, DW-SSFP was used to simultaneously depict brain fiber tracts as well as facial muscle tissue in fetal brain samples.

Methods

Imaging was done on a 7 T MR scanner (Siemens Medical Solutions, Erlangen, Germany) using a custom solenoid coil. Diffusion tensor imaging scans were performed on an ex-vivo fetal brain of 22 weeks gestation using a 3D DW-SSFP sequence with the following imaging parameters: TR = 19.9 ms, TE = 14.9 ms, matrix size 224×168×160, 90×67.5×64 mm^3 FoV, 0.4 mm isotropic spatial resolution i.e. 0.064 mm^3 voxel size, bandwidth 150 Hz/px, 4 non-diffusion-weighted volumes and 56 diffusion-weighted volumes, resulting in a scan time of 7 hours. Eight such acquisitions were co-registered using FSL's FLIRT to correct for B_0 drift and eddy-current distortions [10] and then averaged before further processing. Fiber tracking and visualization were performed using custom-made programs written in C++ using Qt and VTK (http://www.trackvis.org/) [11]. The fiber tracking algorithm is based on the Fiber Assignment by Continuous Tracking (FACT) algorithm [12]. For visualization, fibers were selected based on seed regions and length thresholds.

Results and Conclusion

Figure 1 shows examples of fiber tacking results depicting fibers in white matter and muscle tissue. Tensor-based white matter fiber tracking worked well. Facial, neck, and extraocular muscles are clearly visible at high detail. In summary, it is feasible to image brain samples at high spatial resolution at 7 T using DW-SSFP to depict white matter and muscle anatomy simultaneously.

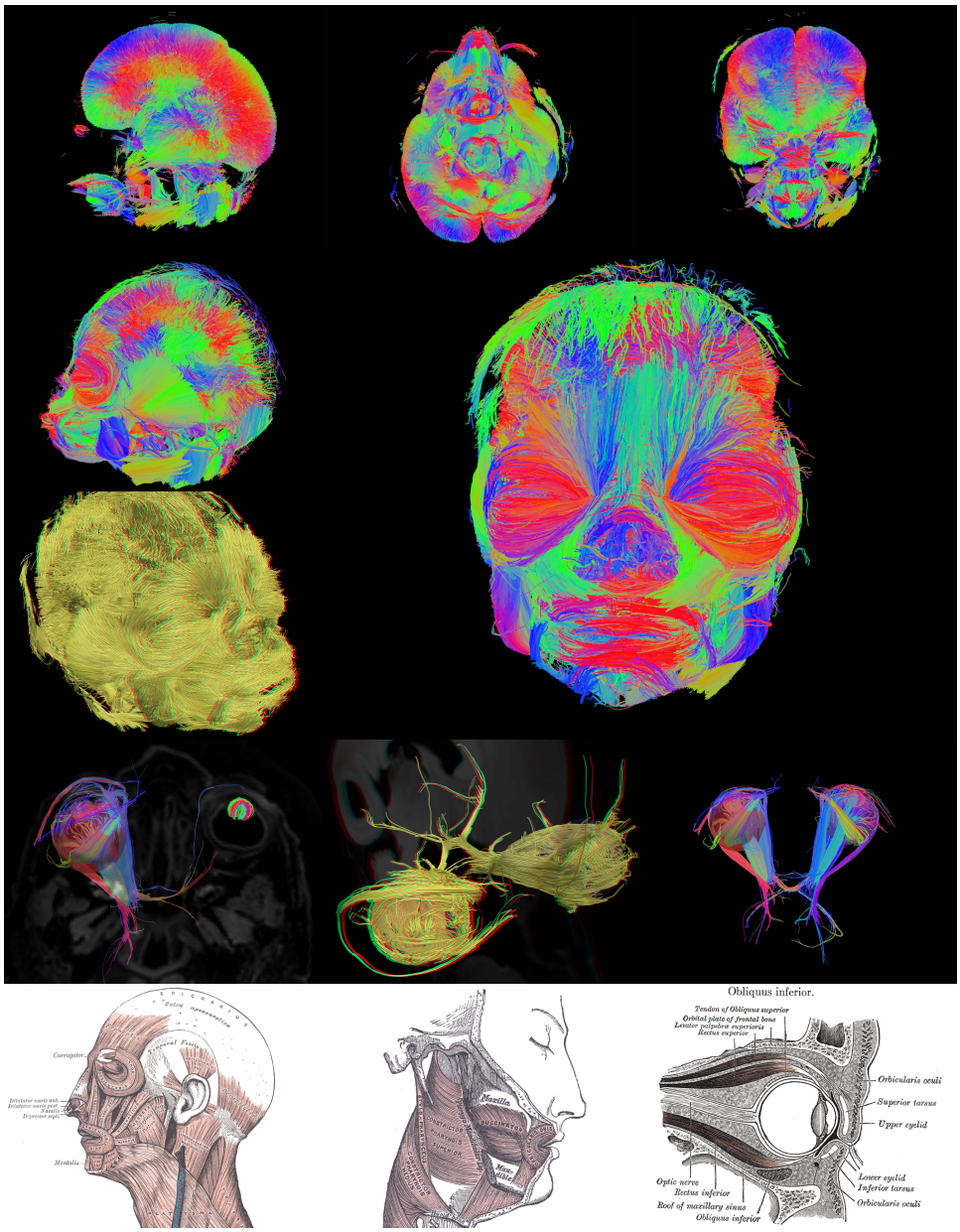

***Figure 1**: Examples of fiber tracking results focused on brain and muscle tissue as well as pictures from an anatomy textbook for comparison [13]. Subfigures with yellow tracts are anaglyph images to provide a stereoscopic 3D effect when viewed with red/cyan glasses.*

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