# Mapping the Anterior Commissure: Turboprop-DTI vs. EPI-based DTI

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**Introduction:** The anterior commissure (AC) is a bundle of nerve fibers that connect, among others, the olfactory bulbs, the amygdaloid nuclei and parts of the cortical regions of the anterior temporal lobes. In the mid-sagittal plane, the AC is located immediately inferior to the column of the fornix, and moving laterally, it bends in an inferior direction, with the most lateral section located immediately inferior to the globus pallidus. Fiber tractography by means of diffusion tensor imaging (DTI) is the only non-invasive technique that can provide estimates of the AC. However, currently, tractography is performed primarily using DTI data acquired with spin-echo echo-planar DTI (SE-EPI-DTI), or variations of this sequence, which suffer from susceptibility-related image distortions, signal loss and pile-up, and image warping due to eddy-currents. Since the AC is located near magnetic field inhomogeneities, the traced AC fibers appear distorted and are often terminated prematurely. Recently, a novel data acquisition and reconstruction technique was introduced, named Turboprop-DTI, which is based on a multiple fast spin-echo (FSE) data acquisition, and therefore is relatively immune to magnetic field inhomogeneities [1]. In this work, the fibers of the AC were traced in normal human subjects using SE-EPI-DTI and Turboprop-DTI data. It was shown that when using Turboprop-DTI datasets, the fiber-bundle of the AC appeared to be consistent with known anatomy, undistorted, and not significantly dependent on the selected seed region. In contrast, when using SE-EPI-DTI data, the fibers of the AC were distorted, often terminated early, and varied significantly when changing the seed region.

**Method:** All scans were performed on a 3T GE MRI scanner (Waukesha, WI). The scanning parameters for the SE-EPI-DTI acquisitions were: TR = 5400ms, TE = 71.8ms, FOV = 24cm x 24cm, image matrix 256x128 reconstructed to 256x256, NEX=5. The total acquisition time was 6 minutes and 18 seconds. The parameters for the Turboprop-DTI acquisitions were: 8 spin-echoes per blade, 5 k-space lines acquired per spin-echo similar to the GRASE sequence, TR=5000ms, FOV= 24cm x 24cm, 192 samples per line reconstructed to a 256x256 image matrix. The total acquisition time for Turboprop-DTI was 18 minutes and 55 seconds. In both scans, the same 36 axial slices, 3mm thick, were imaged. A minimum energy DTI encoding scheme with 12 diffusion directions was used with both sequences [2]. A diffusion weighting of b=900s/mm$^2$ was applied in all directions. For each set of 12 diffusion directions, 2 images with no diffusion weighting (b=0s/mm$^2$) were also acquired. All datasets were interpolated to cubic voxels (0.9375mm x 0.9375mm x 0.9375mm). In SE-EPI-DTI, eddy-current distortions were corrected by registering all DW images to the mean DW image using a 6-parameter 2-D registration algorithm [3]. The SNR was lower in raw images acquired with Turboprop-DTI compared to SE-EPI-DTI. Therefore, a 3x3 low-pass filter was applied on all raw Turboprop-DTI images. Diffusion tensors, eigenvectors and eigenvalues, and fractional anisotropy (FA) values were estimated in every voxel. White matter tracking was performed using the FACT (fiber assignment by continuous tracking) algorithm [4]. Different seed regions were used to trace the AC fibers in both SE-EPI-DTI and Turboprop-DTI datasets, and the results were evaluated.

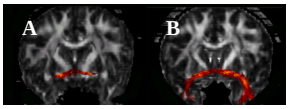


**Figure 1.** Fibers of the AC reconstructed from SE-EPI-DTI (A) and Turboprop-DTI data (B) from the same subject. Tracking based on SE-EPI-DTI produced only part of the AC, while Turboprop-DTI data produced a more complete representation of the AC.

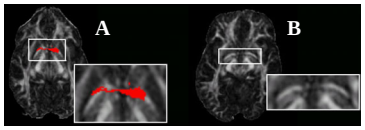


**Figure 2.** The part of the anterior commisure (AC) that is included in this axial slice is characterized by increased curvature in SE-EPI-DTI (A), compared to Turboprop-DTI (B), due to $B_0$-related distortions. The cross-section of the traced AC fibers with this axial plane is shown in red.

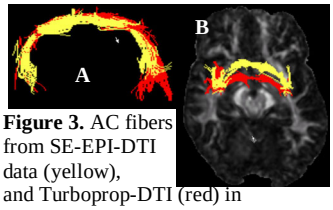


**Figure 3.** AC fibers from SE-EPI-DTI data (yellow), and Turboprop-DTI (red) in coronal (A) and axial views (B). The AC from SE-EPI-DTI was produced by combining 3 separate tracking results and appears discontinuous and distorted.

**Results:** Comparison of Turboprop-DTI images with high resolution anatomical scans showed no significant distortions in the vicinity of the AC in the Turboprop-DTI data. In contrast, significant distortions were found near the AC in the SE-EPI-DTI images. When using a seed region in the mid-sagittal slice, the fiber-bundle produced from Turboprop-DTI data was consistent with the description of the AC from anatomical studies (Fig.1). In contrast, when using a similar seed region, the pathway obtained from the SE-EPI-DTI data was often only a small portion of the one estimated from Turboprop-DTI (Fig.1). In such cases, several other seeds were added near the original seed and fiber-tracking was repeated. However, the SE-EPI-DTI result remained relatively unchanged. Careful inspection of the FA maps from the two datasets revealed that the AC was significantly distorted in the SE-EPI-DTI dataset (Fig.2). For example, the part of the AC that is contained in the axial slice shown in Fig.2 was characterized by significantly increased curvature. However, although the actual shape of the fiber-bundle was modified, the diffusion information in the voxels inside the AC remained approximately the same. Thus, after distortion, the orientation of the primary eigenvectors within the AC did not correspond to the increased curvature of the fiber-bundle. As a result, the estimated pathway was not curved enough during the fiber-tracking procedure, reached the walls of the bundle, and was terminated prematurely. In such cases, additional seeds were selected in the most lateral parts of the AC. These produced parts of the AC that were not mapped using the seed region in the mid-sagittal slice. Although, most of the AC was eventually traced in parts, the combined fiber bundle produced from SE-EPI-DTI datasets did not appear continuous (Fig.3). In Turboprop-DTI, fiber-tracking with seed regions in the most lateral parts of the AC produced similar results to those with the seed region in the mid-sagittal slice. Finally, in cases where SE-EPI-DTI was used for data acquisition, and the distortions were not as severe, the whole length of the AC was mapped but was still distorted compared to the result obtained from the Turboprop-DTI data.

**Discussion:** The development of accurate, noninvasive methods for mapping white matter fiber-tracts in relation to brain pathologies is a goal of critical importance to the neurosurgical community. This study demonstrated the weaknesses of SE-EPI-DTI as a data acquisition method for mapping the fibers of the AC. Tracking based on SE-EPI-DTI produced fibers that were distorted, often terminated prematurely, and heavily dependent on the selection of the seed regions. In addition, Turboprop-DTI, which is relatively immune to artifacts from magnetic field inhomogeneities, was tested for mapping the AC. Fiber-tracking results produced with Turboprop-DTI were undistorted, not significantly dependent on the selection of the seed region, and consistent with known anatomy.

**References:** [1] Pipe JG, ISMRM 2002:p.435. [2] Hasan KM, et al., J Magn Reson Imag 2001;13:769-780. [3] Woods RP, et al., J Comp Assist Tomogr 1998;22:144-154. [4] Mori S, et al., Ann Neurol 1999;45:265-269.