Observation of Anisotropy at Different Length Scales in Optic and Sciatic Nerve Speciments

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Introduction: White matter fiber "tractography" from diffusion MRI data is widely used in the neuroscience community and in clinical research setting to investigate white matter pathways in the human brain. Diffusion weighted images (DWIs) are generally acquired with echo planar (EPI), and suffer from concomitant field [1] and susceptibility related geometrical distortions in the phase encode direction [2]. It should be noted that these EPI distortions are different from the eddy current distortions that are typically corrected in DWI processing. Correction of susceptibility-related distortion requires the acquisition of additional data, either B0 mapping or T2 weighted (T2W) dedicated structural targets and it is not generally performed. In this work, we analyzed the effects of these EPI distortions on DTI-derived tractography results. With the exception of a previous ISMRM abstract [3] we did not find literature data that investigated this potentially important confound.

Materials and Methods:

Methodological Framework: We use diffusion datasets collected with the same parameters except for the direction of phase encoding to probe the effects of EPI distortions on tractography results. If EPI distortions do not significantly affect tractography, we would expect tracts computed from diffusion datasets acquired in the same subject with right-left (RL) or anterior-posterior (AP) orientation of phase encoding to be similar. However, if tractography results turn out to be different we would expect these dissimilarities to be reduced if the EPI distortion in the DWIs is corrected prior to tensor computation.

Data acquisition. Five healthy subjects were scanned with a 3T MR system (GE Medical Systems, Milwaukee, WI) with a single-shot spin-echo EPI sequence with FOV=24x24cm, slice thickness=2.5mm, matrix size=128x128, 66 axial slices. The DWI data set consisted of twenty low b-value images and 60 images with b=1100s/mm2. Two DTI scans were acquired with different phase encode directions (AP and RL). Fast spin echo T2W images were also acquired as anatomical targets for EPI distortion correction.

DTI Processing. All diffusion weighted images for both the AP and RL datasets were corrected for motion and eddy-current distortions. Subsequently, for each AP and RL dataset an additional EPI distortion correction step was either performed, producing "corrected data" or not, producing "uncorrected data". This correction was performed by elastically registering the first b=0s/mm2 image in each DWI set to its corresponding undistorted structural T2WI with B-Splines transformation of grid size 7x7x7. The computed deformation was applied to all DWIs belonging to the DWI dataset [4]. All processing was performed using the TORTOISE software [5].

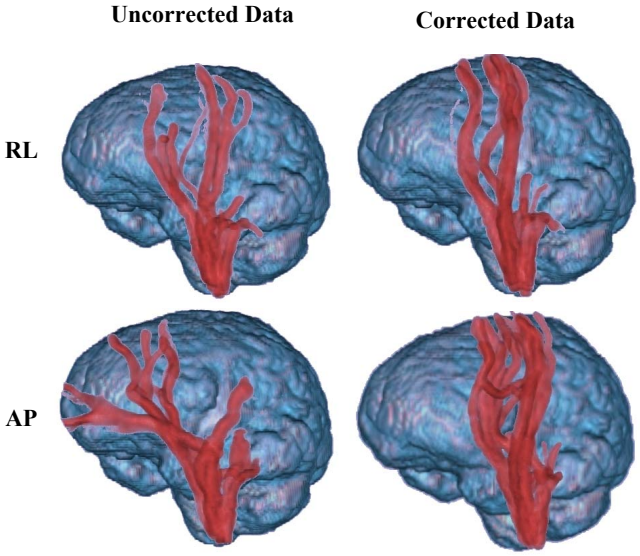

Figure 1. Population average CST and ICP tracts for RL and AP data for both corrected and uncorrected cases. The shade of the red indicates the probability of reaching the voxel from the selected ROIs.

Tractography: Three anatomical pathways were chosen for analysis: cortical spinal tracts (CST), inferior cerebellar peduncles (ICP), and the cingulum bundle. These pathways were chosen because their anatomical trajectory is well known. Both right and left tracts were analyzed. Probabilistic tractography was performed using the same ROIs for each subject, for both corrected and uncorrected data using the FSL software package [6]. The individual tractography results were combined into a general probabilistic tract representation for the population by registering all diffusion tensors to a common space and applying the transformation to the individual tract probability maps.

Results: Figure 1 reports the population average tracts for CST and ICP combined for both AP and RL data, corrected and uncorrected versions. The effect of phase-encoding direction is prominent when we examine the uncorrected data. In the presence of different directions of distortions, both the CST and ICP tracts reached different regions of the brain. This set of tracts were particularly sensitive to distortions in AP direction, which caused the majority of CST become spurious and reach the anatomically incorrect regions of the brain. This behavior was not observed with RL distortion. This can be attributed to the fact that fibers on the inferior aspect of the pons have a large variation of orientation on the AP direction and in the presence of distortions in this direction, they are more likely to go off-track. Additionally, right and left tracts in the population got affected differently from the AP distortion, which resulted in a complete loss of tract symmetry. The corrected AP data did not have most of these problems, indicating that EPI distortion correction reduced the off-track and spurious tracts. The average CST tracts in the corrected AP data reach the cortical regions of the brain and ICP reach the cerebellum, which shows the importance of correction for this case. Distortion correction also improves consistency: the uncorrected RL and AP data have significantly different trajectory signatures, whereas after correction, the shapes of these average tracts get more similar. Additionally, another improvement with correction for the RL data is the increase in probability of reaching the cortical regions of the brain. This can be observed from the stronger tones of red in the cortical regions in the corrected versions of the RL data compared to the fader tones in the undistorted case.

Discussions: The main finding of this work is that EPI related distortions commonly present in diffusion MRI data acquired on clinical scanners have a profound effect on the quality of tractography. We employed a probabilistic DTI tractography approach on a population but similar effects, at least as strong, are anticipated to be observed from streamline tractography or with other diffusion sequences such as high angular resolution (HARDI) based tractography.

References: **1**. Du Y. P. et al., Magn Reson Med, 2002. **2**. Jezzard P. et al., Magn Reson Med ,1995;, **3**. Andersson J.L. et al., ISMRM,2004. , **4**. Wu M. et al., ISMRM, 2007.,**5**. http://www.tortoisedti.org., **6**. Smith S. M. et al., Neuroimage,2004.