

EPI navigator based prospective motion correction technique for diffusion neuroimaging.

Himanshu Bhat¹, M. Dylan Tisdall², Andre Jan Willem van der Kouwe², Thorsten Feiweier³, and Keith Heberlein¹

¹Siemens Medical Solutions USA Inc., Charlestown, MA, United States, ²A. A. Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital, Charlestown, MA, United States, ³Siemens Healthcare, Erlangen, Germany

INTRODUCTION: In diffusion neuroimaging, there are two possible problems due to subject motion: i) images acquired with different diffusion directions are misaligned, leading to erroneous calculation of diffusion parameters, and ii) the diffusion direction being acquired when motion occurs can have signal dropouts. Multiple strategies, both retrospective [1] and prospective [2-6] have been proposed for dealing with this problem. In this work we developed a novel prospective motion correction method for multi-slice single shot diffusion weighted EPI. The technique is similar to the volumetric EPI navigator approach that has been shown for morphometric brain imaging [7].

METHODS: Rigid body navigation is achieved using non diffusion encoded low resolution single shot EPI images as motion navigators (EPI Nav) during the diffusion scan. Two approaches are demonstrated. In the first approach (integrated navigation, Fig 1), a low resolution EPI readout is placed after the 90° excitation pulse and before the diffusion encoding gradient. A corresponding fill time is inserted after the 180° pulse to maintain TE symmetry for the spin echo condition. In this study a 7.5 ms readout was used for EPI Nav leading to a 15 ms increase in TE per slice. In the second approach (interleaved navigation, Fig 2), the EPI Nav and diffusion acquisitions are decoupled. Prior to acquiring slice M for diffusion, slice N is acquired with a 10° flip for EPI Nav. In this work the diffusion series was acquired in 2 interleaves, so the slices M and N were set to be adjacent in space, but TR/2 separated in time in the diffusion scan. For typical TRs of 7-9 sec such a low flip excitation should result in negligible signal loss in the diffusion acquisition. For the interleaved method the EPI Nav acquisition took 10.5 ms per slice. For both techniques over the course of a TR a non diffusion encoded low resolution volume is created from the EPI Nav slices and used for prospective motion correction based on the 3DPACE method which uses a 3D rigid body motion model [8]. The first such volume is used as the reference position by the 3DPACE algorithm. The EPI Nav images are reconstructed using the real-time feedback framework on the scanner and an additional 50 ms delay is introduced at the end of each TR to enable real-time slice position updates for the next TR, based on motion estimates given by the 3DPACE technique. 5 healthy volunteers were scanned with both motion correction techniques, and with a standard non motion corrected single shot EPI sequence. To evaluate the efficacy of motion correction, subjects were deliberately instructed to follow a predefined motion protocol during all three diffusion scans. Imaging was performed on a 3T scanner (MAGNETOM Skyra, Siemens Healthcare, Erlangen). Parameters for the diffusion scan were: FOV: 220x220 mm², matrix: 128x128, b = 1000 s/mm², 60 slices with 2 mm thickness, TE 73 ms, TR 7600 ms, 30 diffusion directions, b/w = 1396 Hz/pixel, GRAPPA factor = 2. Parameters for the EPI Nav scan were: FOV: 256x256 mm², matrix: 32x32, partial Fourier factor = 0.66, b/w = 4596 Hz/pixel, 60 slices with 2 mm thickness (same as diffusion acquisition). For the integrated scheme: TE 88 ms, TR 8610 ms. For the interleaved scheme: TE 73 ms, TR 8300 ms. To demonstrate the independence of the proposed techniques from the b-value, an additional diffusion scan with b = 3000 s/mm² and 60 dirs was collected in one volunteer.

RESULTS: Fig 3 shows the detected rotation and translation parameters, sample EPI Nav images and a single direction diffusion weighted image (DWI) for both motion correction techniques, for two different b-values. Since the EPI Nav image is not diffusion encoded it has good SNR even for a b-value of 3000 and gives reliable motion estimates. Fig 4 shows sample images from both motion correction techniques (top row, 4a: integrated, 4b: interleaved), compared with the non motion corrected sequence (bottom row in both 4a and 4b). The improvement in trace weighted (TW) and fractional anisotropy (FA) images in both motion corrected sequences is apparent. In addition, to evaluate the difference in signal level in the diffusion images between the corrected and uncorrected methods signal ratio in a white matter ROI was measured in the TW image. The integrated motion correction method had a 17.7% signal decrease (due to the increased TE); whereas the interleaved motion correction technique had a 0.57% signal decrease.

DISCUSSION AND CONCLUSION: We demonstrated a novel prospective motion correction technique for diffusion neuroimaging. The proposed methods work independent of the b-value used and do not need retrospective adjustment of the b-matrix. The compromise for the integrated method is the TE and TR increase and the corresponding signal decrease while the interleaved method requires only a small (~10%) increase in minimum TR.

REFERENCES: [1] Rohde et al. MRM 51:103-14 [2] Aksoy et al. MRM 66: 366-78 [3] Zaitsev et al. NeuroImage 31: 1038-50 [4] Kober et al. NeuroImage 59: 389-98 [5] Alhamud et al. ISMRM 2011, 3942 [6] Benner et al. MRM 66:154-67 [7] Tisdall et al. ISMRM 2009, 4656. [8] Thesen et al. MRM 44:457-65.

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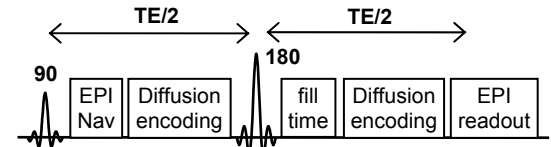


Fig 1: Integrated prospective motion correction technique.

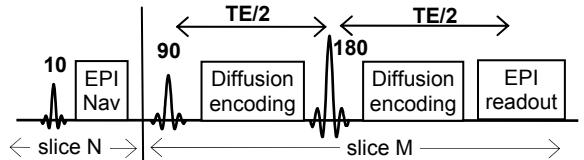


Fig 2: Interleaved prospective motion correction technique.

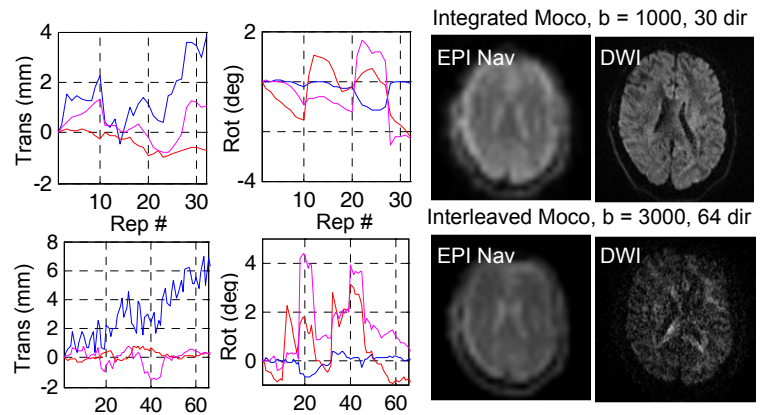


Fig 3: Motion detection and sample EPI Nav images with different b values

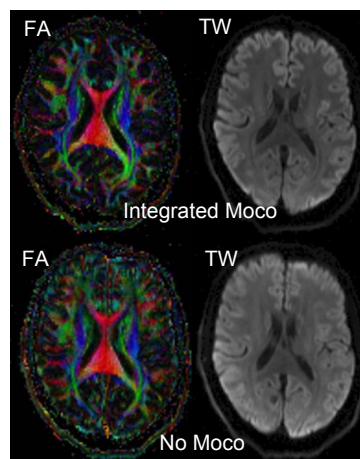


Fig 4a Integrated motion correction

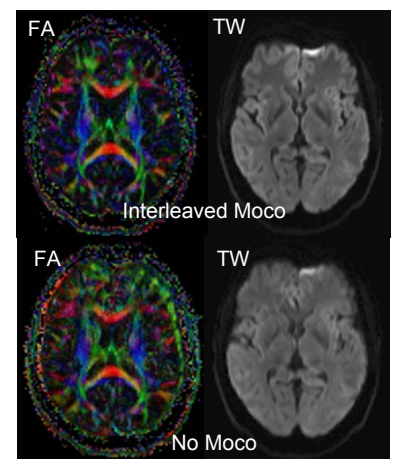


Fig 4b Interleaved motion correction