Image Artifact Correction Tools for Brain DTI Data: Effects on Test-Retest Reproducibility

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Introduction
This study investigated the effects of image co-registration on DTI derived scalar measurements (FA: fractional anisotropy, MD: mean, RD: radial and AD: axial diffusivity) and their across-session test/retest reproducibility. Specifically, we evaluate effects used the first vs averaged b0 volume for eddy current and motion correction in FSL [1]. This pipeline which used the averaged b0 was also compared to the automatic quality control tool DTIPrep Version 1.1.5 [2]. Additionally we tested effects of rotating the b-matrix [3] based on the 6 degrees and 12 degrees of Freedom (doF) correction performed by the FSL software FLIRT [4] and FNIRT [5].

Methods
- Test retest DTI data (9 subjects; 32 ±11 years, 2x2x2 mm3, b=1000 s/mm3, 30 gradient directions, 5 b0, GRAPPA IPAT=2, 4T MRI system) [6]
- Visual check on all b0, DW and sum-squared error images
- Computational check within DTIPrep
- 5 different single software pipelines, all with rotation of the b-matrix [3]:
  1) Fsl6: Standard FSL pipeline with registration to the first b0 image and with b-matrix rotation, based on motion parameters from 6doF registration (FLIRT [4]).
  2) Fsl12: Same as Fsl6, but the b-matrix rotation was based on the motion parameters from the 12doF registration, FNIRT [5].
  3) FsVSM: Standard FSL pipeline with registration to the mean b0 image (after 12 doF co-registration of all 5 b0 images). The b-matrix was rotated based on 6doF.
  4) Fsl12M: Standard FSL pipeline with registration to the mean b0 image (after 12 doF co-registration of all 5 b0 images). The b-matrix was rotated based on 12doF.
  5) DTIPrep: Standard DTIPrep pipeline, which used the iteratively averaged b0 image as a reference during eddy current and motion correction; the b-matrix was updated based on the 6doF registration.
- Data was further processed using TBSS [7]. Test-retest reproducibility errors in the resulting skeleton images were calculated using the absolute difference between test and retest corresponding voxel values divided by the mean of test and retest values and expressed in percent.
- Skeletons were masked with the ICBM label Atlas (1mm) [8] for Regions of Interest (ROI) analysis.

Results

In a Nutshell
Reproducibility errors were significantly reduced:
- When using the first instead of a mean b0 image (FSL pipelines)
- When updating the b-matrix based on 6 doF instead of 12 doF (FSL pipelines)
- When using the software DTIPrep as opposed to FSL.

Conclusions
Significant effects on test-retest reproducibility dependent on:
- Number of b0 images used as a reference during motion correction
- Rotating the b-matrix based on motion parameters
Smallest reproducibility errors:
- DTIPrep pipeline (ROI analysis)
- DTIPrep also revealed many more voxels with significantly reduced reproducibility errors (whole brain analysis).
These results might prompt important considerations for longitudinal DTI and meta-analysis studies where data is pooled or compared.

References