Echo Planar Imaging (EPI) Distortion Correction for Accurate Registration of Perfusion and Anatomical MRI

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PURPOSE

MRI-based Echo Planar Images (EPIs) are sensitive to magnetic susceptibility induced geometric and intensity distortions (Figure 1). Because EPIs form the cornerstone of perfusion-based dynamic susceptibility contrast (DSC) MRIs, geometric and/or intensity correction may therefore improve the accuracy of the perfusion analysis when compared to anatomical data

METHOD

MRI-data from gradient-echo (GE) and spin-echo (SE) pairs of negative and positive phase encoded EPI from **46 glioblastoma patients** were included. The data was analyzed as follows;

- Two correction methods (FSL TOPUP[1,2] and EPIC[3]) were compared that each require both a negative and a positive phase encoded EPI data set from the first dynamic volume (**Figure 1**) to compute off-resonance or displacement field respectively (**Figure 2**).
- TOPUP estimates an off-resonance field using least-square approximation (**Figure 2 a**), whereas EPIC uses an iterative method of gaussian smoothing and cost function minimization to estimate a hessian-based displacement field (**Figure 2 b**).
- High-resolution (anatomical; 3D FLAIR) MRIs where coregistered to low-resolution data (EPI) using FreeSurfer registration[4] for both uncorrected and corrected EPIs (**Figure 3; brain images**).
- Normalized Mutual Information (NMI) whole-brain volume similarity measurements[5] between coregistrated 3D FLAIR and uncorrected and corrected EPIs to measure effect of corrections (**Figure 3; box plots**).
- EPI corrections were performed using a Python pipeline[6].

Figure 1: Raw SE (subj. 372114315)

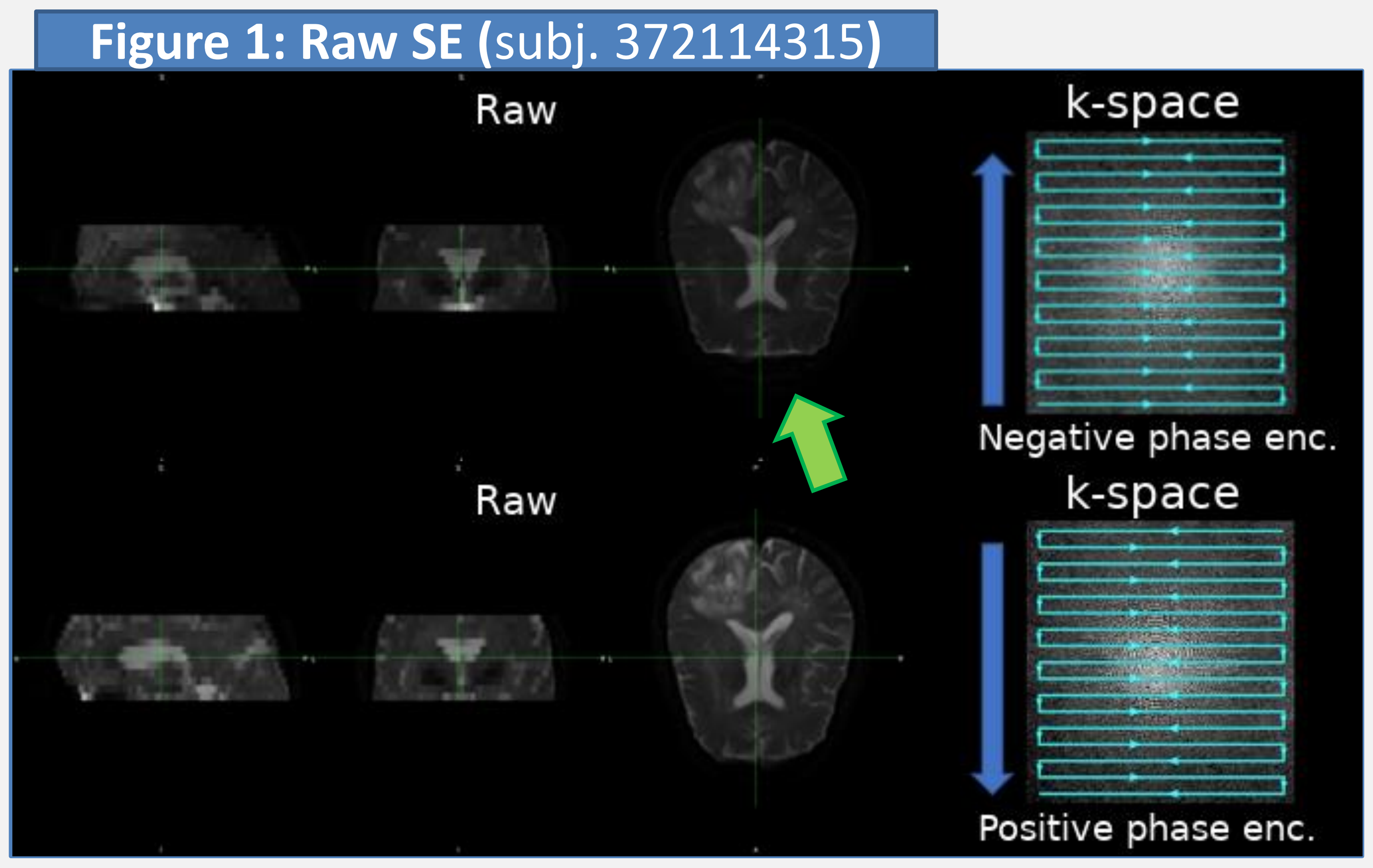


Figure 2: Estimated fields (subj. 636793773)

a

b

DISCUSSION

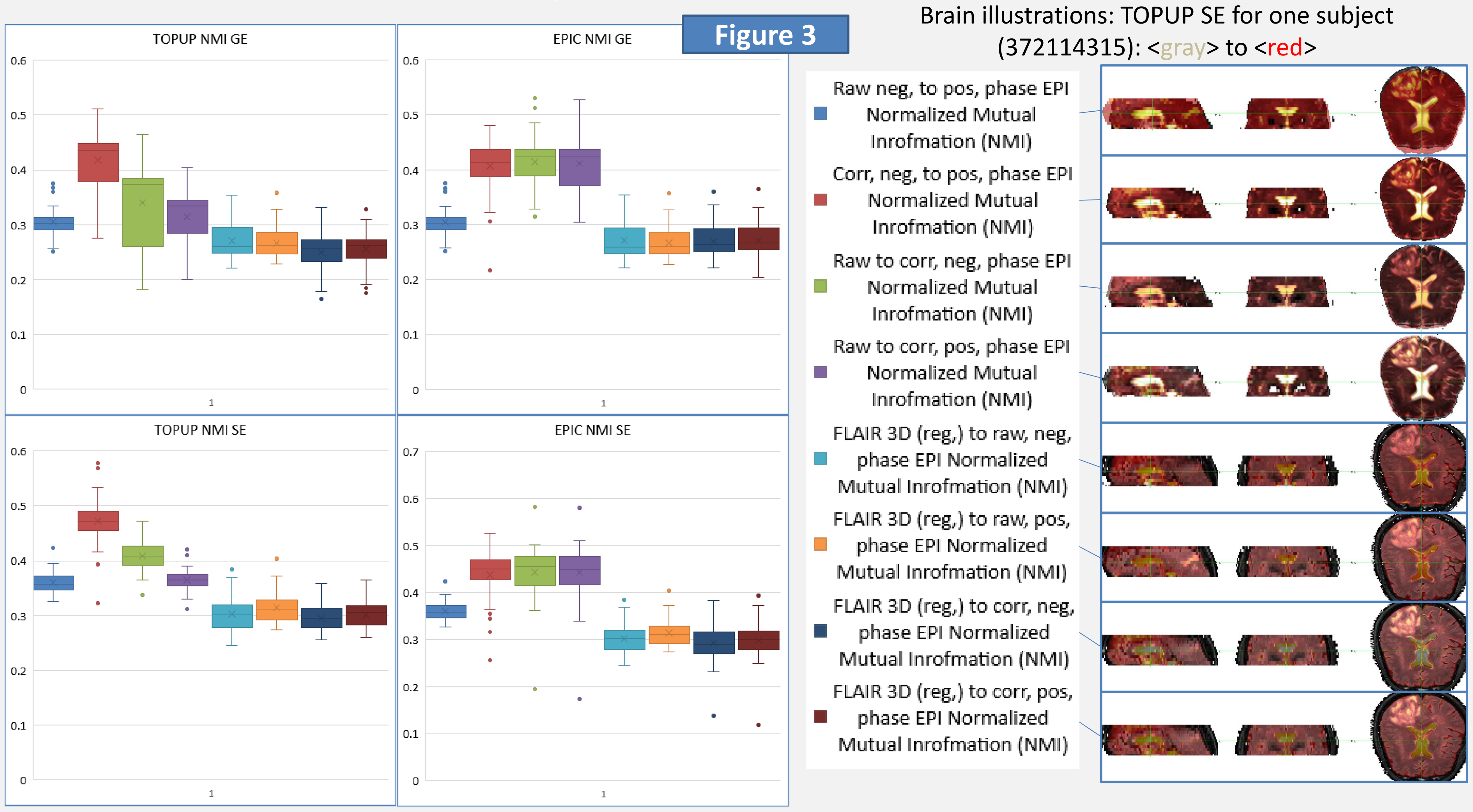
- Higher NMI similarities were found for SE compared to GE (**Figure 3; box plots**), and indicating that using SE pairs may be better than using GE pairs for estimating distortion fields (and performing corrections).
- NMI between EPI images were higher than between EPI and coregistrated 3D FLAIR for both corrected and uncorrected EPIs. Might be explained by high pixel value difference in skull region (**Figure 3; last four brain illustrations, top-down**).
- EPIC leads to distinctively higher NMIs between corrected and uncorrected EPIs than TOPUP (**Figure 3; green, violet**). Might indicate that EPIC correction preserves information better than TOPUP correction.
- Above points motivates to study similarities between corrected and uncorrected brain regions (ex. using MNI (Talairach) atlas) and to perform brain extraction before studying whole brain similarities. Possible added value of corrections on DSC (and thus perfusion analysis) warrants further studies.

RESULTS

The four box plots in **Figure 3** show Normalized Mutual Information between combinations of corrected, uncorrected EPIs and coregistrated 3D FLAIR as described in the legend. See DISCUSSION.

Figure 3

Brain illustrations: TOPUP SE for one subject (372114315): <gray> to <red>



CONCLUSION

- **Our data suggest that EPI correction does not increase the geometric accuracy on a whole-brain level, but instead, may show value for smaller, distortion-sensitive brain regions.**
- **SE EPIs lead to higher image coregistration match regardless of correction method. Uncorrected SE EPIs also give higher coregistration match when compared to GE.**
- **EPIC seems to preserve more information in the images than TOPUP.**

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