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

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Oslo University Hospital is currently running a research project entitled *ImPRESS - Imaging Perfusion Restrictions from Extracellular Solid **Stress***. One of the project objectives is to develop a new imaging processing pipeline for longitudinal (over time) image analysis of the cancerous brain. For each time point (MRI examination), this requires correct coregistration of the lower resolution perfusion images with a more detailed higher resolution T_1 (or T_2) MR image. The longitudinal analysis also includes a nonlinear coregistration technique to track any morphological changes on the high-resolution MRIs between each examination. In turn, by adding the coregistration of the low-resolution perfusion data, this will allow us to track the corresponding perfusion changes as observed through the high-resolution MR images.

However, the fast acquisition Echo Planar Imaging (EPI) sequence used to obtain the dual Gradient Echo (GE) - Spin Echo (SE) perfusion data may introduce several geometrical and intensity distortions. Thus, voxel-by-voxel, the perfusion data do not necessarily match the corresponding T_1 structural image. This is mainly caused by tissue-dependent magnetic field inhomogeneities of the fast EPI readout[1] The most severe artefact in the relevant data is geometric "stretching" of the images with negative phase encoding direction (in the so-called k-space acquisition) along the anterior-posterior image axis. This stretching is less severe on images with a positive phase encoding direction. The work presented in this thesis are comparisons of various EPI distortion correction methods, preferably FSL topup[2] and EPIC[3] but also other possible methods such as ANIMA[4]. **Figure 1** shows an example correction using FSL topup.

1.Jezzard, P. & Balaban, R. S. Correction for geometric distortion in echo planar images from B0 field variations. Magnetic Resonance in Medicine 34, 65–73 (1995).

2.Andersson, J. L. R., Skare, S. & Ashburner, J. How to correct susceptibility distortions in spin-echo echo-planar images: application to diffusion tensor imaging. NeuroImage 20, 870–888 (2003).

3.Holland, D., Kuperman, J. M. & Dale, A. M. Efficient Correction of Inhomogeneous Static Magnetic Field-Induced Distortion in Echo Planar Imaging. Neuroimage 50, 175 (2010).

4.Hedouin, R. et al. Block-Matching Distortion Correction of Echo-Planar Images With Opposite Phase Encoding Directions. IEEE Transactions on Medical Imaging 36, 1106–1115 (2017).

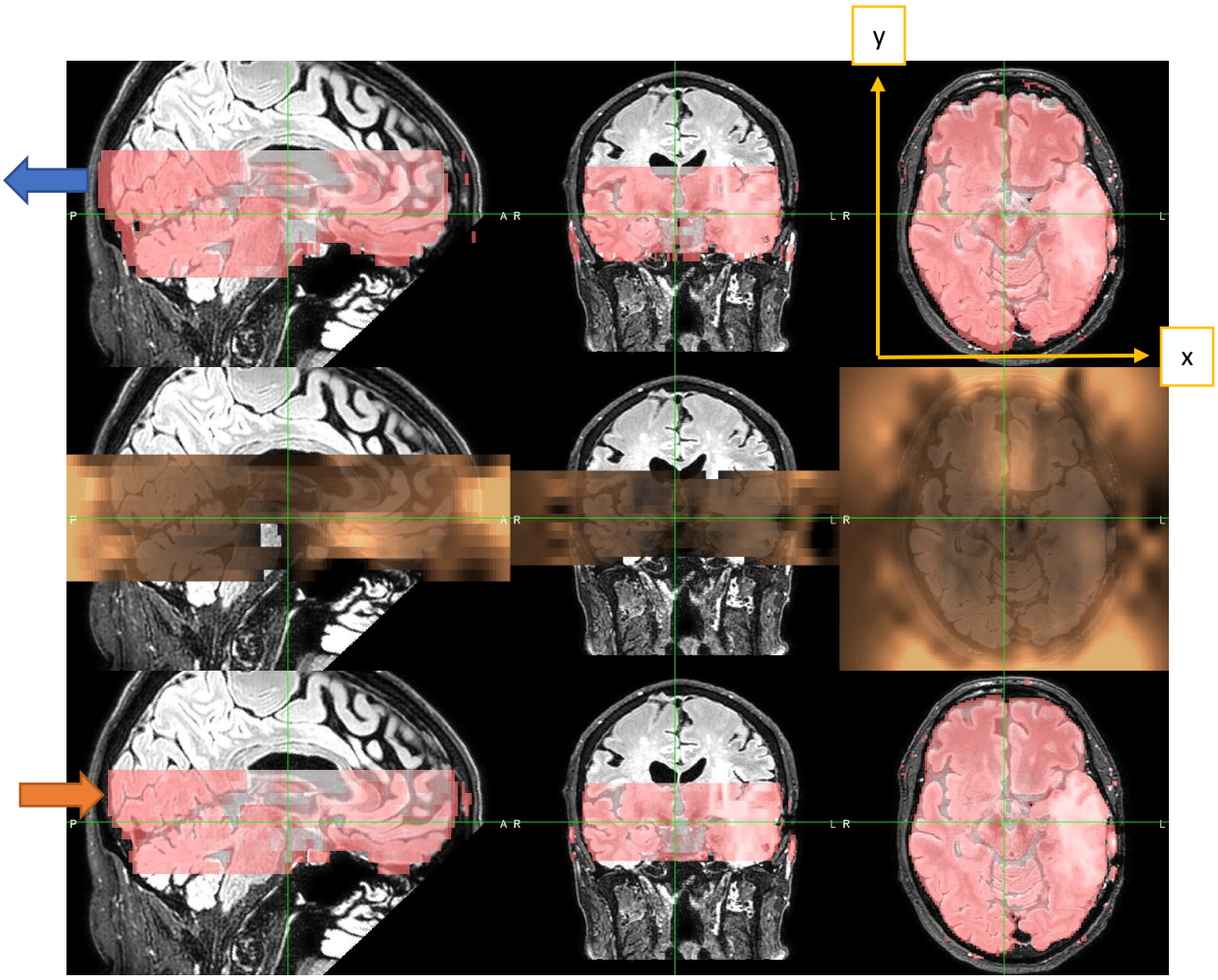

Figure 1 Uncorrected and corrected EPI SE (pink) and off-resonance field (copper) on top of T_2 FLAIR. From top row and downwards; First row: Uncorrected EPI SE negative phase encoding direction. The main distortion shown is the geometric stretching along the negative phase-encoded direction (-y), as illustrated with the blue arrow. Second row: The off-resonance field from FSL topup calculated from positive and negative phase encoding direction EPI SE images. Third last row: Corrected negative phase encoded EPI SE image from EPI in first row, using the field in the second row. The main improvement seen is the correction of the stretched image, as illustrated with the orange arrow.