Clinical relevance of EPI distortion correction in presurgical fMRI at 7T

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Introduction: As a non-invasive method, fMRI is increasingly being applied in presurgical planning for patients with brain tumors, epilepsy or cortical dysplasia. It allows essential brain functions close to pathologies to be localized and spared in resection, ensuring that patients retain the ability to move, speak and remember after the operation. Ultra high magnetic field (7T) in fMRI provides higher time-series SNR, which allows the resolution to be increased or the measurement time reduced. Acquired data suffer, however, from geometric distortions due to field inhomogeneities, which increase linearly with field strength. The most common solution to this problem is to measure the distribution of these inhomogeneities in a single reference scan, the so called static field map (FM)[1]. Such information is subsequently used to shift fMRI voxels to the undistorted space. The effectiveness of static unwarping at high field, especially in case of pathological brains, is not well known. A previous study in a small group of patients demonstrated activation mislocalization with potential clinical consequences[2]. It is therefore important to further evaluate the clinical relevance and the effectiveness of static distortion correction (DC) at 7T in a heterogeneous group of patients.

Materials and Methods: Eight patients, referred for presurgical fMRI planning, were studied. Diagnoses included brain tumour, epilepsy and cortical dysplasia. The measurements were performed at 7T Siemens scanner using 24 or 32 channel coils. Patients performed between 5 and 12 runs of block-designed (4 OFF and 3 ON) chin and hand movement tasks. EPI time series were acquired with 56 volumes, in plane resolution 1.8 mm x 1.8 mm, slice thickness of 3.3 mm, TE/TR = 22/2500 ms, GRAPPA factor 2. The number of slices was varied to obtain full brain coverage in each patient. Additionally, MGE data (TE = 4.6, 9.3, 14.1), with geometry matching the EPI, were acquired for the calculation of the fieldmaps. Phase and magnitude data from all channels were saved separately.

Analysis: Static fieldmaps were calculated using the Hermitian inner product implemented in a MATLAB toolbox developed in-house[3]. Distortion correction, using FMs, was performed with FSL's FUGUE for all EPI time series. Subsequently slice time correction, motion correction, co-registration between the runs and GLM analysis was carried out in SPM8 for both unwarped (DC) and original distorted (noDC) data. Activated voxels were identified for all patients and the two cases (DC and noDC) and were overlaid on reference GE magnitude images.

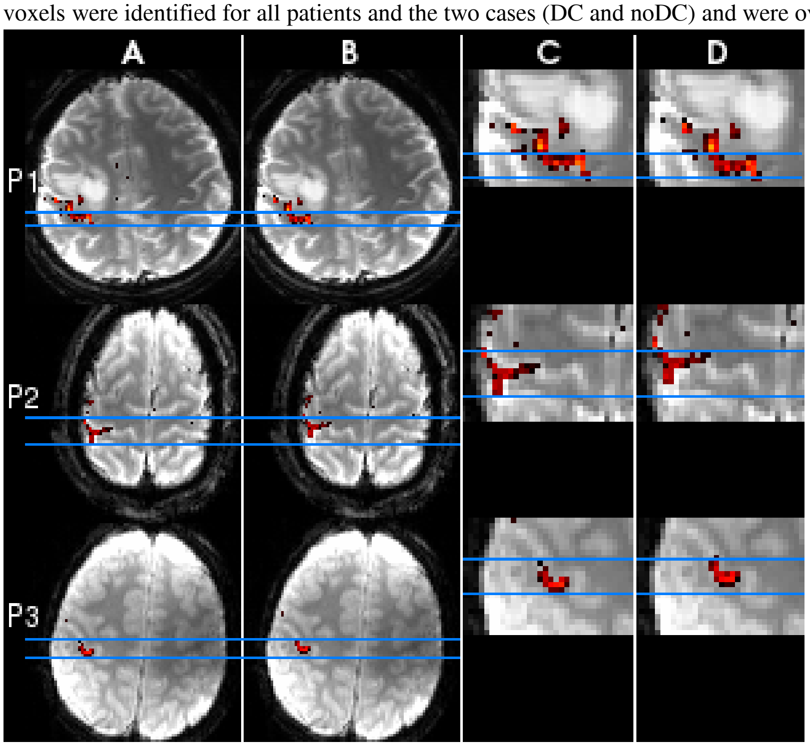

Fig.1 Activation results (red) for 3 patients (3 rows) overlaid on GE reference images. Column: A) activated regions estimated with no distortion correction (noDC) in preprocessing pipeline, B) activated regions estimated after DC, C) magnification into region of interest for noDC case, D) magnification into ROI for DC case.

Results: Comparison of DC and no DC EPI runs with reference GE magnitude images showed that observable warps in the original EPI data were effectively removed by static distortion correction in all cases. Figure 1 shows results for 3 patients (P1, P2 and P3), for which geometric distortion in the original EPIs was prominent in the hand region of the primary motor cortex. In the first patient (P1), with diagnosed glioma, the activation shifted by 1 voxel following distortion correction. This increased the margin between the tumour and the activation by ~ 1.8 mm. In the second patient (with astrocytoma, P2) the distortion correction shifted the activation by 2 voxels (~ 3.6 mm), which moved it from the post-central gyrus to the central sulcus / pre-central gyrus. Similarly, for the third patient (with focal cortical dysplasia, P3) the hand activation was shifted by 1 voxel, which was sufficient to correctly reposition the activation from the postcentral gyrus to the central sulcus.

Discussion: Distortions of about 1 - 4 mm were found in the primary motor cortex. These could be corrected using static fieldmap calculated from reference MGE data. The shift of activation in the results of patient P1 could potentially lead to a surgical decision of more aggressive tissue resection. In case of P2 and P3 shifts of 1.8 and 3.6 mm could lead to misidentification of the central sulcus. This could be more problematic still in cases with grossly altered morphology and tissue contrast.

Conclusion: Geometric distortion of fMRI results could lead to clinically relevant mislocalization of activation. Additionally, correct repositioning of the activation around pathology could affect decisions about resection margins. It is, hence, important to transform the fMRI data into a distortion-free space to draw correct clinical decisions.

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References: [1] Jezzard, P, Balaban, RS (1995) Magn Reson Med 34:65–73. [2] Robinson, S, et al., (2010) Proc. of ISMRM, #2302. [3] Robinson, S, Jovicich, J (2011) Magn Reson Med 66:976–988.