Dynamic unwarping of EPI geometric distortions using Interleaved Dual Echo with Acceleration (IDEA) EPI

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Introduction

Echo planar imaging (EPI) permits fast fMRI and is highly sensitive to the BOLD signal. However EPI suffers from geometric distortions in the phase encode direction caused by field inhomogeneity. Corrections using field maps (1), PSF maps (2,3), or gradient reversal (4,5,6) have been proposed. Accurate correction improves image registration and even group results (7). However, subject motion during the scan may invalidate 'static' reference data as distortion changes with head position (8,11). This problem can be addressed by dynamically updating the field maps during the scan (4,8,9,10). **Dynamic field maps can be obtained using IDEA EPI** (Interleaved Dual Echo with Acceleration EPI), originally developed for Nyquist ghost compensation (12). Two ghost-free images are simultaneously sampled under the positive and negative EPI readout lobes. The echo time difference ΔTE between images (ESP~0.5–0.9ms) allows a field map to be obtained for each fMRI volume.

Methods

Phantom and *in vivo* IDEA EPI scans were acquired on Siemens 3T Trio (64x64, 25 slices, TE=35ms, FoV=224mm, TR=2s, ESP=0.7ms, P-A phase encoding, 30 volumes). *In vivo* time series with and without intentional head motion were acquired (N=2). A gradient-echo field map (TE=10/12.46ms, 64x64 matrix, 64 slices) was also acquired. Dynamic unwarping was performed using a modified version of SPM8 Fieldmap *prior* to image realignment. For reference, a conventional correction was done using the static field map in SPM8's 'Realign&Unwarp', which incorporates estimates of the susceptibility-by-movement interaction (11). Performance was assessed by visual inspection, and comparing temporal SNR (tSNR).

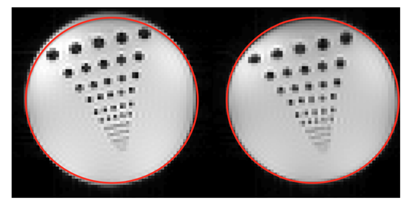

Fig 1: Phantom image before and after unwarping with the IDEA EPI field map.

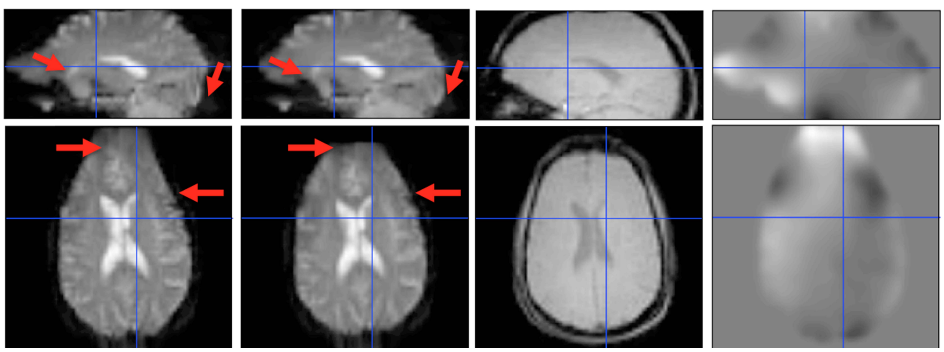

Fig 2: Distorted image and image unwarped with IDEA EPI field maps (first and second column), undistorted FLASH scan, and the field map derived from the IDEA EPI data.

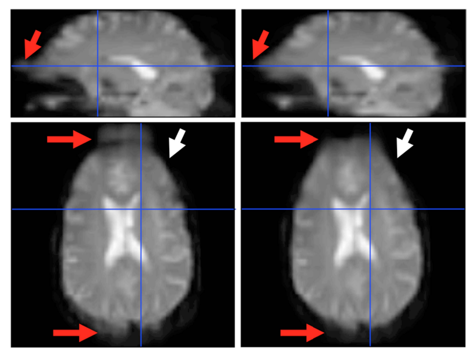

Fig 3: Average image over 30 volumes with deliberate head motion after static (left) and dynamic IDEA EPI unwarping (right).

Results and Discussion

Fig.1 shows a phantom image before and after successful IDEA EPI field map unwarping. The decreased image distortion is seen by illustrated by the circular outline. Fig.2 shows an *in vivo* volume before and after dynamic correction, an undistorted FLASH image, and the corresponding IDEA EPI field map. Fig.3 shows the average over 30 scans with deliberate motion after applying static (left) and the prosed dynamic (right) correction. Average tSNR over brain voxels was very similar for both methods in the "no motion" scan (<0.6mm, <1°), indicating that the dynamic approach introduces only little additional variance when it is not strictly needed (tSNR 62.27 vs. 64.76; loss 3.84%). Realignment parameters for the motion-infested scan showed peak translations/rotations of ~6mm/5°. Here, dynamic unwarping gave better tSNR than static unwarping (tSNR 15.63. vs. 14.60; gain 7.03%), and less residual motion-related fluctuations. It is conceivable that signal voids in IDEA EPI data result in low-SNR field maps, which will be explored further.

Conclusions

Our data indicate that IDEA EPI holds promise for dynamic distortion correction of fMRI data, and in the presence of subject motion may outperform conventional approaches. Dynamic unwarping may also be of particular benefit in cases where subject exclusion cannot be afforded (e.g. clinical N=1 fMRI) and aid the analysis of otherwise unusable data.

References [1] Jezzard P, MRM 1995 [2] Zeng H, MRM 2002 [3] Zaitsev M, MRM 2004 [4] Morgan PS, JMRI 2004 [5] Andersson JLR, Neuroimage 2002 [6] Holland D, Neuroimage 2010 [7] Cusack R, Neuroimage 2003 [8] Hutton C, Neuroimage 2002 [9] Weisskopf N, Neuroimage 2005 [10] Visser E, ISMRM 2011 [11] Andersson JLR, Neuroimage 2001 [12] Poser BA (MRM, *in rev.*)

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