

In-plane motion correction for Diffusion-Weighted 3D Multi-Slab EPI

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Introduction

The diffusion-weighted 3D Multi-Slab EPI sequence (DW 3D MS EPI) (1) is a high SNR diffusion weighted imaging acquisition enabling true isotropic resolution for demanding diffusion studies (Fig. 1a). Although the sequence has a higher SNR efficiency than 2D DW-ss-EPI, stemming from the prolonged TR required for full brain coverage, the total acquisition time becomes still long (20-50 s per diffusion direction) when high isotropic resolution is required (~1.5 mm³). To cope with involuntary subject motion, some type of motion correction is therefore warranted. In this work, we detail a retrospective 2D in-plane motion correction method as an initial step to a full 3D motion correction procedure, tailored for multi-slab acquisitions. The method is divided into two steps, intra- and inter-slab motion correction, where the intra-slab motion correction is performed prior to Fourier transformation along the slice encoding (k_z) direction.

Material & Methods

A healthy volunteer was scanned using an 8-channel head coil (Invivo Hi-Res Head Coil, Gainesville) on a 3T MRI system (GE DVMR750, GE Healthcare, Milwaukee). Relevant scan parameters were: TR = 4600 ms, TE_{image/navigator} = 78/128 ms, slab matrix = 144x144x10, number of slabs = 24, FOV = 220 mm, slice thickness = 1.5 mm, yielding a final nominal resolution of 1.5mm³ (3.4 μ l). Three b₀ volumes and 15 non-collinear diffusion encoded directions with b = 1000 s/mm² ('b1000') were collected. The subject was instructed to slowly rotate in the left-right direction. For the *intra-slab* motion correction, the navigator images (echo #2, blue) corresponding to each k_z encode with in each slab were realigned (in-plane only) to each other using a simple sum-of-squares metric (2). The estimated motion parameters were subsequently applied to each k_z encoded image (echo #1, green), followed by 2D phase correction and Fourier transformation along the k_z direction (Fig. 1b). Next, *inter-slab* motion correction was performed, utilizing the overlapping slices between adjacent slabs. First, a mid-brain slab was chosen as reference. The edge slices within the two adjacent slabs were registered to the corresponding overlapping slices in the reference slab. Following this, the realignment procedure was repeated outwards for the next neighboring slabs etc., effectively "locking" all slabs together to a full coherent volume (Fig. 1c).

Results

The upper row in Fig. 2 shows an isoDWI volume without motion, with and without the motion correction applied. The second and third row shows motion-corrupted data, for isoDWI and an arbitrary diffusion encoding direction respectively, with and without the suggested motion correction applied.

Discussion & Conclusion

For 2D single-shot scans like standard DW-EPI and fMRI, 3D rigid body motion correction is often applied to align each volume (formed by the stack of 2D slices each TR) to a one selected reference volume. In these cases, with a TR of a few seconds, it may be reasonably well justified to ignore *intra*-volume motion and to only correct for motion *between* the volumes this way (i.e. diffusion directions). For DW 3D MS EPI however, one full brain volume takes significantly longer to acquire (20-50 s), and assuming that no motion has occurred within each full brain volume makes less sense. We have here presented a simple method to correct for *intra*-volume motion in 3D MS EPI, with a motion time resolution of one TR (here 4.6 s). *Inter*-volume 3D motion correction may be added as a final correction step in addition to, and following, the in-plane corrections proposed in this work, to also address slowly varying nodding type motion between diffusion directions while acknowledging the aforesaid time resolution limitations.

References

[1] Engström et al., ISMRM 2011 p. 3519; [2] Friston et al., Spatial registration and normalization of images. Hum Brain Map 2012;2:165-189.

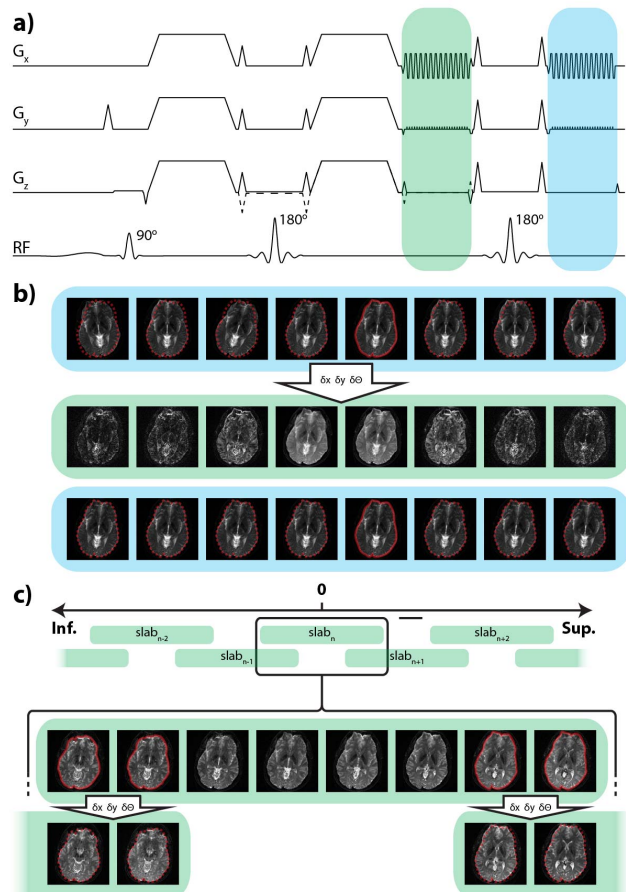


Figure 1. a) The DW 3D MS EPI sequence. b) The *intra-slab* motion correction procedure, c) *Inter-slab* motion correction procedure. Red solid line indicates reference image for realignment.

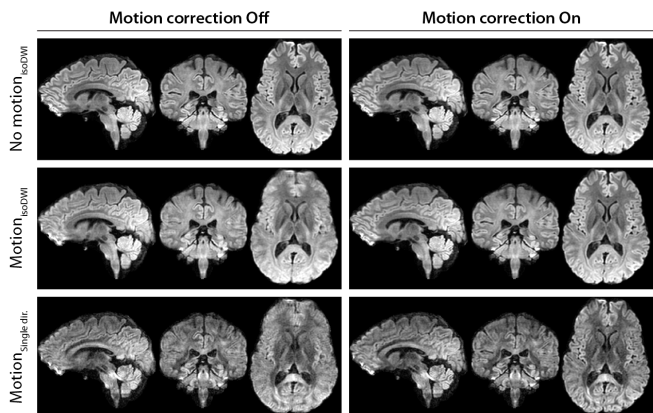


Figure 2. Performance examples of the suggested motion correction method - left column is with the motion correction off, right column with the motion correction on.