Motion Correction for DWI with Segmented EPI: Comparison Between an Iterative Parameter Space Searching Technique and Conventional Navigator Echo Correction

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Introduction:

Multi-segment diffusion-weighted imaging (DWI) techniques are inherently sensitive to patient movement because of inter segment phase differences generated by motion occurring during the large diffusion gradients. Navigator echo correction techniques attempt to measure these phase differences for each segment with projections or low-resolution images and use this phase information to correct the images. An alternative approach is to use an iterative parameter space search to determine the optimal phase difference parameters for each segment. (These parameters are the 0^{th} order phase, 1^{st} order phases along the x and y directions). Previously the performance of this technique was qualitatively assessed based on its application on moderately (b = 350 mm^2/s) diffusion-weighted images acquired from a single subject using two and four segment interleaved segmented EPI.[1] The objective of the present work was to provide a quantitative assessment of the performance of this method in comparison to the 1D navigator echo motion correction method. The comparison is carried out using DWI (b = 600 mm^2/s) from 8 adults and 5 neonates.

Methods:

Eight healthy adult volunteers and five neonatal subjects were imaged using a 3.0 T MRI system. Informed parental consent was obtained for all neonatal patients and the research ethics board approved all MRI studies. DWI was performed with an 8-segment EPI sequence with diffusion weighting (b =600 mm^2/s) provided by velocity compensated diffusion gradients.[2] Image acquisition was triggered by a pulse oximeter on the finger of the adults and the foot of the infants (delay time = 300ms for adults and 100ms for neonate). Navigator echo data was collected for each segment for offline phase correction of inter-segment phase differences caused by motion. Imaging parameters included: 4 slices [adult], 10 slices [neonatal], 128 x 128 matrix size, bandwidth = 100kHz, FOV = 240mm [adult] or 160mm [neonatal], TE = 135 ms, TR = 4[adult] or 10 [neonatal] R-R cardiac intervals.

Motion correction was performed using a post-processing technique similar to that previously reported[1] and applied to 2 and 4 shot DWI EPI. However, we modified the search procedure to reduce postprocessing time (two minutes for 8 segment acquisition). Initially we applied a coarse search of just the 0^{th} order phase and these values are used as the start point for the Gauss-Newton minimization of the 0^{th} order phase parameters. Two subsequent minimization steps were performed using the result of the previous minimization as the start point for the next minimization with an additional 1^{st} order phase parameter added to the search. 1^{st} order phase correction in the y direction was applied using the refocusing reconstruction technique.[3]

The relative efficacy of the motion correction techniques were quantified using the artifact to signal ratio (ASR) defined by:

$$ASR = \frac{S_{GHOSTING} - S_{NOISE}}{S_{BRAIN}}$$

where S_{BRAIN} is the mean signal amplitude from the brain, $S_{GHOSTING}$ is the mean signal in the background region displaced from the head in the phase encode direction and S_{NOISE} is the mean signal in the background regions displaced from the head in the read direction .

Statistical analysis was performed (in SPSS) using a 3-way ANOVA with the factors: correction technique (navigator, iterative search); diffusion direction; and slice number. ASR was the dependent variable for the analysis.

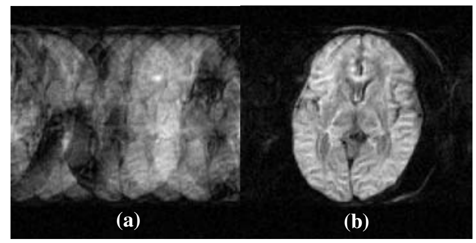

Figure 1. Neonatal DW image before (a) and after (b) minimization motion correction

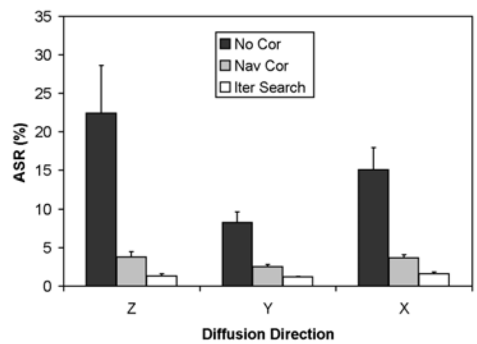

Figure 2. Artifact level in adult subjects with no correction (No Cor), 1D Navigator Echo Correction (Nav Cor) and Iterative Parameter Space Search Correction (Iter Search)

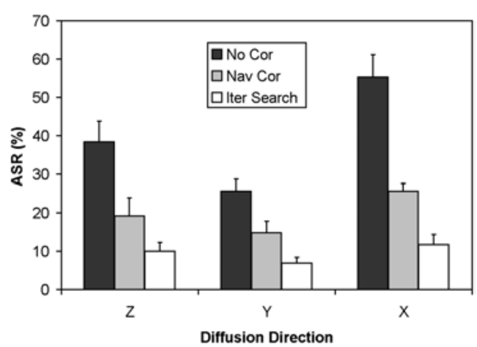

Figure 3. Artifact level in neonatal subjects with no correction (No Cor), 1D Navigator Echo Correction (Nav Cor) and Iterative Parameter Space Search Correction (Iter Search)

Results:

The image ASR values for the three diffusion directions averaged over slice and subject are presented for the adult (figure 1) and neonatal (figure 2) subjects. For the adult subjects there was a significant main effect observed for correction technique [$F(1,7) = 29.79$, $p<0.005$]. A significant main effect was also observed for motion correction technique in the neonatal patients [$F(1,4) = 23.33$, $p<0.01$]. The iterative search correction technique significantly reduced the ASR by a factor of 2.4 in the adults and a factor of 2.1 in the neonates compared to the navigator technique.

Conclusions:

The iterative search technique considered here performed significantly better than the conventional navigator echo technique in the both the adult and neonatal subjects.

References:

1. Robson MD *et al*, MRM, **38**:82-88 (1997)
2. Clark CA et al, J. Magn. Reson, **142**, 358-363 (2000)
3. Miller KM *et al*, MRM, **50**:343-353 (2003)

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