MR-based and Optical Prospective Motion Correction for High Resolution DWI with RS-EPI

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Introduction: Recently, multiple approaches have been proposed to perform motion correction for diffusion imaging using optical tracking with cameras [1,2] or using MR-based methods which perform real-time registration between volumes [3-5]. In this study, we demonstrate the application of and compare both optical and MR-based motion correction to high-resolution diffusion-weighted imaging using readout-segmented EPI (RS-EPI).

Methods: *1) MR-based motion correction:* The RS-EPI-DWI sequence is shown in Fig. 1. Here, k-space is traversed in multiple segments or "imaging blinds". To remove motion-induced phase errors between imaging blinds, the central blind is acquired after a refocusing pulse (Fig. 1). Here, the MR-based motion correction used each central blind to reconstruct a low-resolution volume (i.e. navigator volume) that could be registered to the first navigator volume. When the detected motion between the reference and the current navigator volume was larger than a threshold, data acquired within the last 2 TR's were reacquired. Reacquisition of data within the last 2 TR's was necessary to ensure that both the imaging and the navigator volumes have no motion within the volume (i.e., intra-volume motion).

2) Optical motion correction: An MR-compatible camera was mounted on the head coil and took images of a checkerboard pattern mounted on the patient's forehead (1,6). The video signal from the camera was transmitted through fiber-optic link in order to reduce interference on the MR-images. The images were processed by an external laptop and motion parameters were sent in real-time to the scanner to adapt scan-plane. When motion was detected, the data acquired in the last 500ms was reacquired to compensate for the latency of the optical tracking system.

RS-SAP EPI diffusion-weighted images were acquired on two human volunteers using a 3T whole-body MRI unit and an 8-channel head coil. The scan parameters were: 256×256 with blade/blind width = 32, FOV = 24 cm, #blinds = 9, slice thickness = 5 mm, TR = 10 s. Volunteers were asked to perform in-plane motion three times during the scan.

Results: Fig. 2 shows the results of MR-based prospective motion correction and Fig. 3 shows the results of optical prospective motion correction. For both cases, the image quality was significantly improved after motion correction. In the presence of motion, the scan time was significantly longer for MR-based correction than for optical correction because for MR-based correction, the previous two volumes needed to be acquired, which cost an additional scanning time of 2xTR (=20s). For optical correction, this time was 500ms. It was also observed that real-time rotation of gradient axis resulted in ghosts in the central blind images (Fig. 4). Depending on the hardware, this ghosting can cause registration of navigator volumes for MR-based correction to fail for large head rotations.

Discussion & Conclusion: Optical and MR-based prospective motion correction methods were demonstrated and applied to high-resolution DWI using RS-EPI. Results indicate that both methods are effective at removing motion artifacts. However, optical tracking had lower additional scan due to each occurrence of motion (20s vs. 500ms). On the other hand, motion estimates obtained from optical tracking were more robust to ghosting as compared to MR-based tracking. Elimination of these ghosting artifacts from the navigator volume requires more sophisticated ghost correction methods.

References: [1] Aksoy et al, MRM, 2011 [2] Zaitsev et al, Neuroimage, 2006 [3] Thesen, MRM, 2000 [4] Benner et al, MRM, 2011 [5] Kober et al, Neuroimage, 2012 [6] Forman et al, Med Imag Anal, 2011 **Acknowledgements:** This work was supported in part by the NIH (1R01EB008706, 1R01EB008706S1, 5R01EB002711, 1R01EB006526, 1R21EB006860), the Center of Advanced MR Technology at Stanford (P41RR09784), Lucas Foundation, and Oak Foundation.

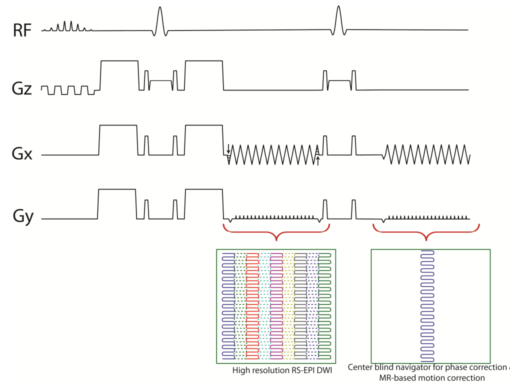

Figure 1 – *The RS-EPI diffusion weighted sequence used for this study. k-space was traversed in segments called "blinds". The central blind which was acquired after the refocusing pulse was used for phase and MR-based motion correction.*

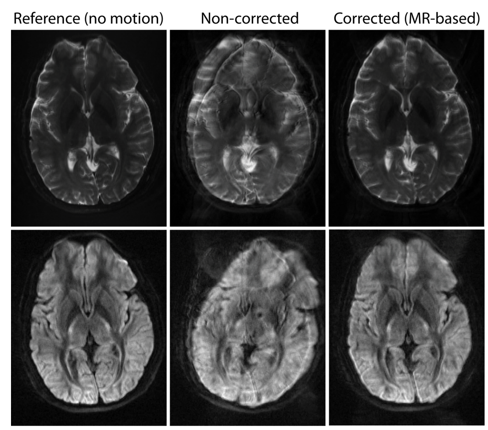

Figure 2 – *B0 and DW images corrected with MR-based method (last column, top/bottom respectively) are free of motion artifacts present in the uncorrected images (middle column).*

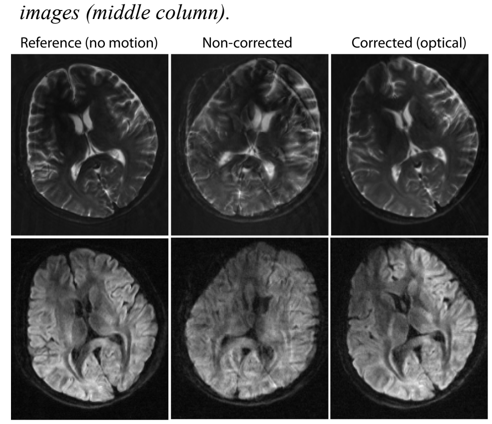

Figure 3 – *B0 and DW images corrected with optical method (last column, top/bottom respectively) are free of motion artifacts present in the uncorrected images (middle column).*

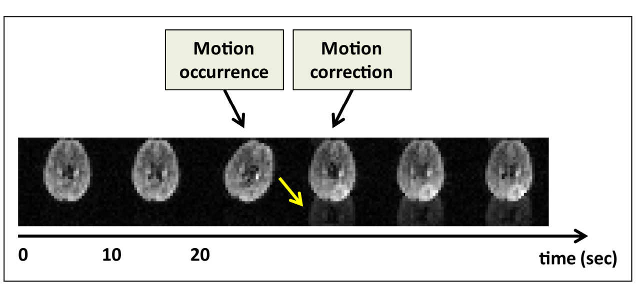

Figure 4 – *Example navigator images before motion, after motion and after motion correction. The ghosting occurs due to the rotation of the gradients (yellow arrow). The severity of ghosting increases for large head motion and this reduces the robustness of MR-based correction. Optical tracking is immune to the effects of ghosting.*