Benefits of Optical Prospective Motion Correction for Single-Shot DTI

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INTRODUCTION: Involuntary patient motion causes pixel misregistration and changes the effective diffusion-encoding, which, in turn, results in erroneous estimation of diffusion tensors or higher-order variants (1-3). The most common method of motion correction for DTI is retrospective coregistration of diffusion-weighted volumes to a reference volume. However, retrospective correction methods cannot repair incomplete diffusion-weighted volumes, spin history effects, or non-equidistant sampling of the diffusion-encoding direction space. In this study, we propose to use an adaptive optical tracking system (4) to correct for motion artifacts in single-shot EPI DTI and aim to demonstrate the advantages of this prospective approach over retrospective volume-to-volume realignment.

THEORY AND METHODS: • *Prospective Optical Motion Correction* – A small camera was mounted on an 8-channel head coil and acquired images of a self-encoded marker (5) attached to the subject's forehead (4). The video frames were processed on an external computer. The patient's pose was determined at a rate of 25Hz and the geometry update was sent back to the sequencer in real-time so that the scan volume followed the subject's head with minimum delay.

• *Experiments* – A single-shot DTI-EPI sequence was used (TR/TE=10sec/75msec, FOV=24cm, 96x96 matrix, 36 3mm slices @ 1mm gap, b=1000 sec/mm^2, # diffusion directions = 25 (+3 b=0)). The volunteer was asked to perform mixed (in-plane) shaking and (through-plane) nodding motion throughout the scan, once every ~15 seconds. This scan was repeated with & without prospective motion correction. The data without adaptive motion correction was also reconstructed after retrospective volume-to-volume realignment with SPM5. For reference, two additional datasets were obtained where the subject was asked to stay still and prospective motion correction was turned off and on. Since miniscule subject motion was inevitable even in this case, the dataset with prospective correction was deemed to be the reference. For all datasets, fiber tractography was also performed by planting seed points within the corpus callosum and cortico-spinal tracts. Three quality metrics were used to quantify the quality of reconstructed FA maps and fiber tracts: 1) Correlation coefficient of FA maps between each four datasets and the reference dataset; 2) Normalized High Spatial Frequency Energy (NHSFE) relative to reference dataset to assess the sharpness of the image (6) and 3) the average length of reconstructed cortico-spinal tracts (CST).

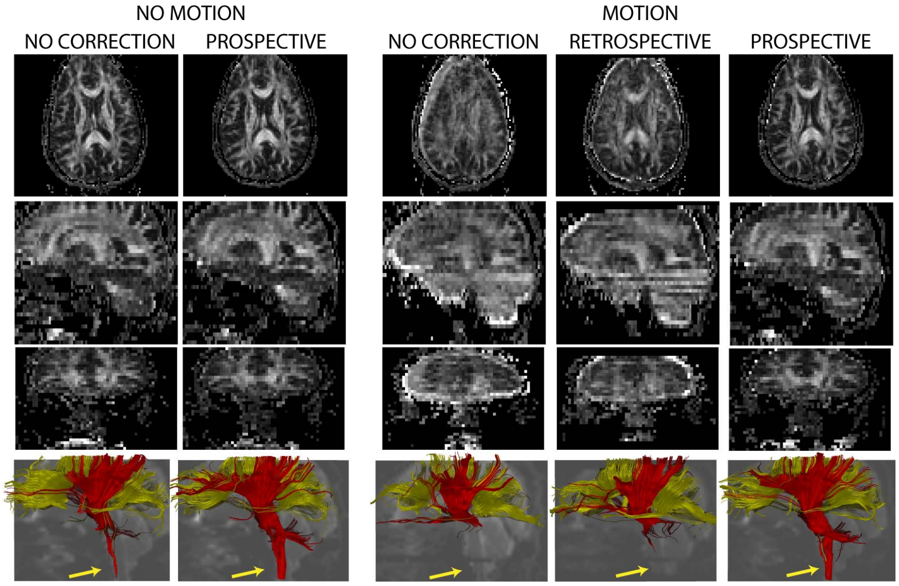

Fig. 1 *– Reconstructed FA maps and fiber tracts with and without prospective and retrospective correction.*

RESULTS: Fig. 1 shows FA maps and reconstructed fiber pathways for all five datasets. FA maps reconstructed from prospectively corrected data had a higher correlation coefficient with the reference dataset (no motion & prospective cor.) and a higher NHSFE compared to retrospectively corrected dataset (Tab. 1). The higher NHSFE indicates an image with less motion-related blurring. Unlike the prospective correction, the retrospective correction was unable to resolve intra-volume motion and spin-history effects in superiorly located slices. For inferior slices, another challenge for retrospective correction was the elimination of slices that were corrupted due to motion. The low signal level on inferior slices caused some of the corrupted slices to be included in the DTI analysis by mistake. With prospective correction, a rescanning strategy was used, which reacquired a slice if severe motion was detected. This provided an external and reliable method to eliminate the corrupted slices, which was most evident from the fiber tracking experiments in which a better visualization of cortico-spinal tracts was achievable when prospective correction was used (yellow arrow and Tab. 1).

Table 1 *- First row: Correlation coefficient of the four different datasets with the reference (i.e. no motion & no correction, first column in Fig.2). Second row: Normalized High Spatial Frequency Energy for each dataset. High energy at higher spatial frequencies imply a sharper image, hence less motion related blurring. Third row: Average length of the reconstructed cortico-spinal tracts.*

	NO MOTION		MOTION		
	NO CORRECTION	PROSPECTIVE (ref)	NO CORRECTION	RETROSPECTIVE	PROSPECTIVE
correlation coef.	0.655	1	0.488	0.484	0.733
NHSFE	0.976	1	0.883	0.916	1.007
Mean CST length (mm)	490	646	352	469	615

CONCLUSION: This study showed that retrospective volume-to-volume realignment of diffusion-weighted scans is insufficient even for single-shot EPI data. The application of a prospective motion correction system clearly improved the accuracy of DTI data. The quasi-instantaneous response is of real-time optical motion correction is of considerable benefit over MR-based prospective techniques, such as PACE (7) or PROMO (8), which are severely handicapped by the lagging response when used in long TR sequences, such as DTI.

References: [1] Rohde, MRM, 2004 [2] Aksoy, MRM, 2008 [3] Leemans, MRM, 2009 [4] Aksoy, ISMRM, 2008 [5] Forman, MICCAI, 2010 [6] Ooi, MRM, 2009 [7] Thesen, MRM, 2000 [8] White, MRM, 2010 **Acknowledgements**: This work was supported in part by the NIH (5R01EB002711, 5R01EB008706, 3R01EB008706, 5R01EB006526, 5R21EB006860, 2P41RR009784), Lucas Foundation, Oak Foundation, and GE Healthcare.