Motion Correction in Diffusion Spectrum Imaging Using Simulated Diffusion Images at Multiple b Bands

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TARGET AUDIENCE: Those using single shell and multiple shell diffusion schemes such as diffusion spectrum imaging (DSI) in applications where motion may be a problem.

PURPOSE: It has been reported that subject motion and scanner drift cannot be estimated correctly from diffusion weighted (DW) images due to lower signal and contrast variations of anisotropic diffusion for different directions of DW gradients.[1] Both problems can be avoided by using simulated DW images.[2] However, simulated DW images based on mono-exponential diffusion cannot match the image contrast of the acquired DW images for a wide range of b values as in DSI.[3] The motion correction method using the simulated DW images has been optimized using the DW images with deliberate motion for single shell DW imaging. The method has also been applied to DSI by estimating the tensor at multiple b bands, to account for multiple exponential diffusion weighting.

METHODS: The overall motion correction procedure is shown in Figure 1. The motion was first estimated in reference to a b=0 volume (usually the first volume) using the FSL's mcflirt with a cost function of 'normmi' and a rigid body transformation. The tensor was calculated from the motion corrected data. Subsequently, the motion was estimated in reference to the simulated images using the FSL's flirt with a cost function of 'corratio' and a rigid body transformation. For DSI with 257 DW directions and the maximum b = 5000, the DW images were grouped into 5 consecutive bands with boundaries at b = 900, 1700, 2500, and 3900. The number of DW directions in the 5 bands was 16, 30, 43, 93, and 75. Within each band the tensor was estimated and the simulated DW images were calculated using the tensor of the band. Diffusion images were acquired from six normal volunteers (4 for single shell and 2 for DSI) with a 3-Tesla MR scanner using the double spin echo sequence. The subjects made deliberate head movements during the DW imaging of the single b value at b=2000 s/mm^2 of 50 DW directions. In the DSI experiment there was no deliberate motion and six b=0 volumes were distributed in time to be used as a reference for the motion. The DW images were analyzed using the GQI method in DSI Studio. The effect of motion correction was measured from FA histograms of the whole brain white matter and the cingulum tracts.

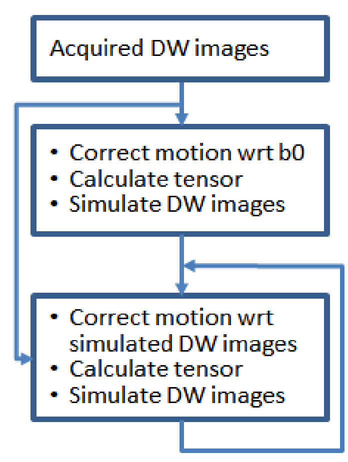

Fig. 1. A functional block diagram. The bottom block can be iterated.

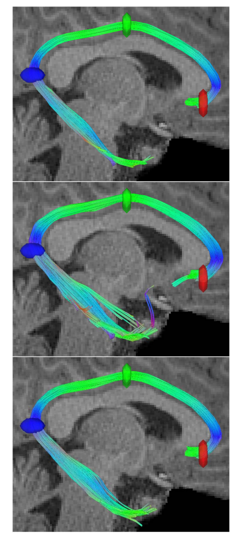

Fig. 4. Cingulum tracts from acquired, (top) and motion corrected using mono- and multi-exponential (bottom) DW.

RESULTS: For the single shell DW imaging, the motion correction was confirmed to be sufficient within 1 iteration through the FA histograms (closer to the FA histogram obtained in the absence of deliberate motion) and cingulum tracts. For DSI, the image contrast using the mono-exponential diffusion was indeed quite different from the acquired DW images, while the multi-band method was able to match the image contrast (Fig. 2). The better matching of the image contrast resulted in improved motion estimation in DSI (Fig. 3), which improved the cingulum tracts (Fig. 4).

CONCLUSION: The motion estimated in reference to the simulated DW images improved the motion estimation of DW imaging. For DSI the simulated DW images should be calculated from the tensors that were estimated within the band of the target b value due to the multiple-exponential diffusion weighting. This correction method has been applied to a large scale diffusion imaging study of people with autism where motion is a problem.

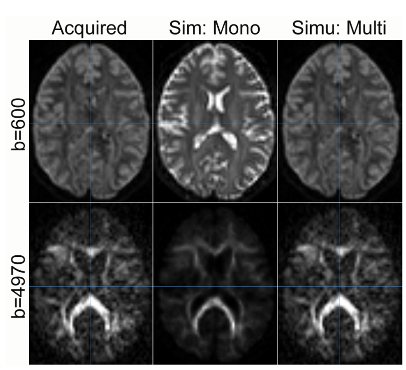

Fig. 2. Comparison of image contrast between the acquired and the simulated DW images using the mono and multiple exponential DW in DSI.

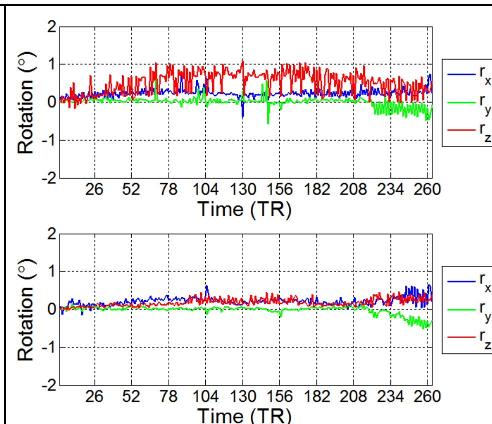

Fig. 3. Estimated rotation using the mono (top) and multiple exponentially simulated DW. images.

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