Motion Correction in Diffusion Weighted SSFP Imaging of Cartilage

T. S. Kim[1], K. L. Miller[2], G. E. Gold[3], J. M. Pauly[1]

[1]Electrical Engineering, Stanford University, Stanford, CA, United States, [2]FMRIB, John Radcliffe Hospital, Oxford, United Kingdom, [3]Radiology, Stanford University, Stanford, CA, United States

Introduction

Diffusion weighted imaging (DWI) is potentially useful in the diagnosis of early cartilage damage. Steady-state DWI (SS-DWI) obtains high SNR images of cartilage with strong diffusion weighting despite the short T_2 of cartilage [1]. However, the sensitivity of DWI to even small subject motion makes it difficult to achieve the high resolution needed for the assessment of cartilage. A refocusing reconstruction has been used to correct the motion artifacts [2]. However, motion in the knee is simple enough to be approximated to a combination of rigid body translation and rotation [3]. In the presence of diffusion gradients translational motion causes a uniform phase shift and rotational motion causes a linear phase variation for every TR [3,4]. In 3DFT acquisition this linear phase variation corresponds to random k-space displacement of each readout trajectory, results in regions of k-space having local densities below the Nyquist rate in phase encoding direction and produces artifacts. Uniform re-sampling method [5,6] using an additional 2D navigator can be applied to correct the k-space displacement without significant computational complexity and allow much faster reconstruction that could be applied clinically, where the delay in image reconstruction is an important consideration. We take the uniform resampling idea originally developed for spin-echo EPI [7], and show that it can effectively correct SS-DWI acquisitions, provided motion can be modelled as rigid body translation and rotation.

Methods

To correct motion-induced artifacts an axial low-resolution spiral navigator was inserted in front of every readout gradient. The linear phase variations in readout direction were ignored because they are relatively small. Linear phase variations in phase encoding direction were corrected by measuring the shift of the maximum signal point in navigator, which corresponds to k-space displacement and re-sampling the data into uniformly spaced sample points. A specific sample point with maximum average signal magnitude in the navigator was picked and used to cancel out the uniform phase shift for each data frame caused by the translational motion. In vivo images of the patella-femoral joint were acquired from a healthy subject on a 1.5 T Signa LX scanner with 40 mT/m maximum gradient amplitude and 150 mT/m/s maximum gradient slew rate using a 7.4 cm surface coil centered on the patella. A SS-DWI sequence was used to image the knee cartilage, which has short T_2 (20 ~ 40 ms). Axial images were gathered through the articular cartilage covering a $14\times14\times4.8$ cm^3 FOV in a $256\times192\times16$ matrix for $0.5\times0.7\times3.0$ mm^2 voxel resolution. Navigators were acquired in the k_z = 0 plane over a 14×14 cm^2 FOV in a 1-interleave 54-sample-point spiral trajectory. The sequence utilized TR = 30 ms and $\alpha = 25°$. Diffusion gradient of strength G = 40 mT/m was applied for τ = 5.5 ms, causing signal attenuation in cartilage equivalent to b = 630 s/mm^2. The subject was stabilized using a knee-high plastic brace loosely mounted on the patient bed.

Results

Figure 1 shows diffusion weighted knee images from a healthy volunteer with and without uniform re-sampling motion correction. Motion corrected images in the bottom have higher resolution and reveal more detailed structures which have been blurred in the images in the left column.

Conclusion

Motion correction method using uniform re-sampling (URS) can achieve high resolution diffusion weighted imaging for rigid body motion, such as occurs in the knee with relatively small computational complexity.

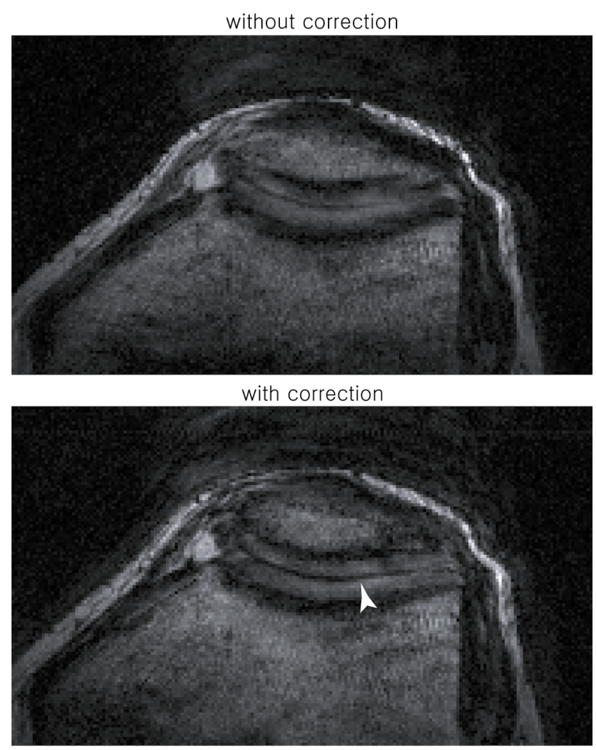

Figure 1. Diffusion weighted knee images with and without motion correction. The image in the bottom shows more detailed structures than the one in the top. For example, the cartilage free surface (arrow) is much better in the corrected image.

References

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