Image Distortion and Inter-Station Discontinuity Reduction using High Order Eddy Current Correction in Whole Body Diffusion Weighted Imaging

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INTRODUCTION

Whole body diffusion weighted imaging (WB-DWI) has been shown as an efficient and effective way of predicting and monitoring cancer treatment response [1-3]. Axial-plane single shot echo planar imaging (EPI) is predominantly used in WB-DWI; the nature of EPI sequence makes WB-DWI images prone to B0 inhomogeneity and eddy current induced distortions. Three orthogonal diffusion directions are often used to minimize the influence of diffusion anisotropy [2], which makes the eddy current related distortions particularly problematic as these distortions are diffusion axis dependent, creating misregistration among DW images and/or the T2 weighted image. Note that the constant and linear eddy currents are often well compensated by pre-emphasis on the majority of commercial scanners. However, the uncompensated high order eddy current (HOEC) can still generate significant image distortion due to the large field of view and coverage used. WB-DWI is often performed as a multi-station approach; image intensity or tissue shape discontinuities can also occur at station boundaries due to uncorrected HOEC. In this paper, we use a combined prospective and retrospective compensation method [4] to correct HOEC induced distortion in WB-DWI. Volunteer results show that the proposed method can significantly reduce in plane distortion/misregistration and station boundary discontinuities.

METHODS

We briefly summarize the HOEC correction method [4] below. It consists of three main components: HOEC calibration, pulse sequence level prospective correction, and image reconstruction level retrospective correction. HOEC calibration is a one-time per-system calibration. It collects 4D eddy current field measurements (3D in space, 1D in time), fit them with polynomial or spherical harmonic model in space, and exponential model in time. Based on the eddy current time constants and amplitudes as well as sequence gradient waveforms, we obtain the HOEC field during the EPI readout and prospectively modify gradient waveforms and B0 offsets on a per-slice basis for compensation. Note that not all HOEC can be compensated in the pulse sequence; all residual terms are corrected in image reconstruction using geometric and intensity corrections.

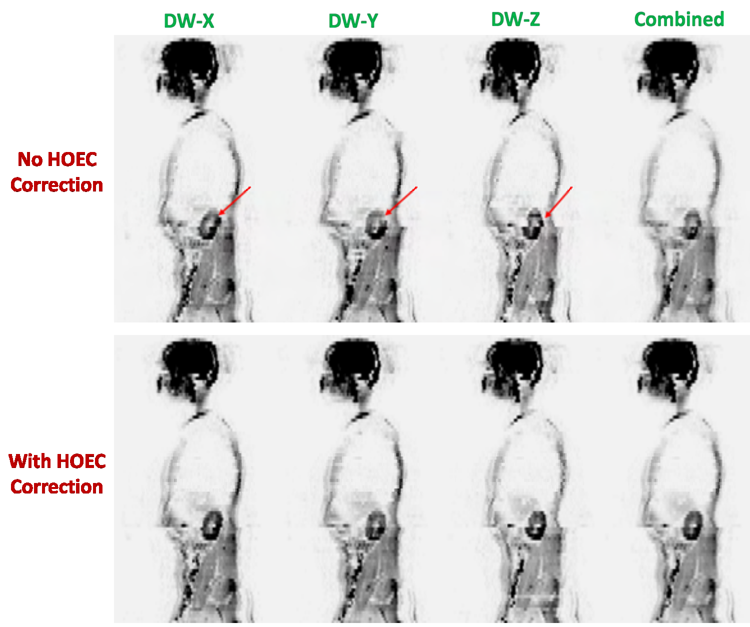

Fig. 1. Sagittally reformatted 3-station WB-DWI images without (top row) and with (bottom row) HOEC correction. The shapes of body and kidney (marked by arrows) are significantly different in the uncorrected images, causing a blurry combined image. These differences in shapes are substantially reduced with HOEC correction.

RESULTS

WB-DWI images without and with HOEC compensation were acquired on a GE 3T scanner using the Stejskal-Tanner DW EPI sequence with diffusion directions on physical X, Y, and Z axes, respectively. The combined images were also calculated to show the trace weighted images. Three stations were acquired, each with superior-inferior coverage of 30 cm. The remaining parameters were: parallel imaging factor = 2, TE = 61 ms, TR = 5s. The top row of Fig. 1 shows the sagittally reformatted images without HOEC correction. There is significant shape difference and misregistration between the DW-X, Y, and Z images, which is especially apparent at the kidney area (marked by the red arrows) as it is right at the boundary of stations 2 and 3. The misregistration also makes the combined image look blurry. DW images with HOEC correction are significantly more registered spatially and therefore generate a sharper combined image.

The reduction of misregistration is more appreciable by comparing the axial source images near the boundary of stations 2 and 3. The top row of Fig. 2 shows that without HOEC correction, the shapes of the body and kidney are quite different between DW-X, Y, and Z images, generating blurring and ghosting in the combined image. The bottom row shows that with HOEC correction, both the body and kidney shapes are spatially registered, generating a much improved combined image.

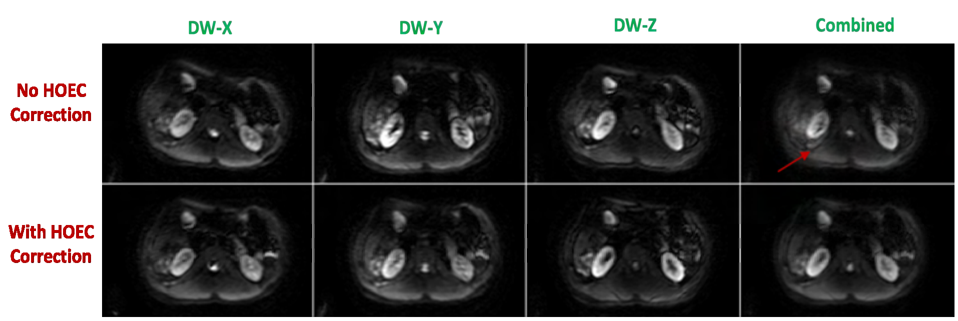

Fig. 2. Images from an axial slice near the boundary of stations 2 and 3 of the same the data as Fig. 1. Misregistration between DW X, Y, and Z uncorrected images and the amount of misregistration reduction achieved by the HOEC correction are more obvious than when viewed sagittally.

CONCLUSION

Residual HOEC can lead to significant, direction dependent image distortion in DW images, which often cause blurry and misregistered trace weighted images/ADC maps. In WB-DWI, the distortion can also manifest itself as discontinuities between station boundaries because HOEC is in general not symmetric on the superior and inferior sides of the scanner. Volunteer results have shown that the proposed correction is effective in reducing eddy current induced image distortion and improving WB-DWI image quality.

REFERENCES

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