Improved diffusion-weighted body imaging using high-order eddy current correction and smart combination

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In the clinic, single-shot diffusion-weighed Echo-Planar imaging (DW-EPI) has become an important technique for body applications. One issue with DW-EPI is the signal loss in regions of the liver due to cardiac motion. Our group has presented a post-processing strategy, called smart combination (1), to mitigate the signal loss. This technique requires data acquired at multiple diffusion directions. It is well known that there is strong geometric distortion that varies along different diffusion direction when single spin-echo (SSE) diffusion scheme is used (2). To avoid mis-registration in smart combination, dual spin-echo (DSE) diffusion (3) has to be employed. This leads to longer TE, reducing the signal from liver. Recently, high-order eddy-current (HOEC) correction has been proposed to correct for the geometric distortion (4), especially with SSE diffusion. The goal of this work is to demonstrate the feasibility of generating good liver DW-EPI results with high SNR, reduced signal loss, and minimal mis-registration by applying HOEC correction and smart combination on SSE DW-EPI.

Method

HOEC correction uses pre-acquired calibration information of high-order eddy-current to modify the data acquisition and enhance the reconstruction to correct for the geometric distortion in each individual diffusion-weighted image (4). The results obtained with SSE have minimal geometric distortion. This allows the generation of the combined diffusion-weighted image with minimal mis-registration between different diffusion directions. The conventional algorithm calculates the combined image by multiplying each individual image together. Therefore, signal loss due to cardiac motion in any image will be propagated to the final image. To avoid this issue, the smart combination technique calculates the combined image by weighting each individual image based on its signal intensity before the multiplication (1).

Volunteer data were acquired on a GE Discovery 450w scanner using breath-hold DW-EPI with DSE, SSE with and without HOEC correction, and the following imaging parameters: b = 500 s/mm^2, FOV = 40x40 cm^2, slice thickness = 8 mm, gap = 2 mm, matrix size = 80x128, NEX =2, 16 slices with diffusion on three orthogonal directions. The source images were reconstructed using enhanced reconstruction and then processed with both conventional and smart combination algorithms.

Results and Discussion

Figure 1 shows the combined diffusion-weighted images generated using conventional method for data acquired with a) SSE, b) DSE, and c) SSE+HOEC correction. As pointed to by the arrow in a), there is artifact due to mis-registration between the three source images caused by geometric distortion. The DSE technique can reduce the ghosting artifact, but scarifying SNR (low signal intensity) due to increased TE (Fig. b). The HOEC correction technique can also effectively reduce the ghosting artifacts in data acquired with SSE while preserving high SNR (Fig. c). However, the signal loss (as pointed to by the arrow in Fig. c) still exists. With the use of smart combination on data acquired with SSE and HOEC correction (same data as used in c), a high quality liver image (d) can be generated. It is noticed that the signal loss is different in Figs. (a~c). This is due to the random correlation between the timing of the diffusion gradient and the cardiac motion in different scans.

In conclusion, it is proven feasible to simultaneously reduce signal loss due to cardiac motion and mis-registration (distortion) due to eddy current in liver DW-EPI with SSE while retaining high SNR. This greatly improves quality of body DWI applications.

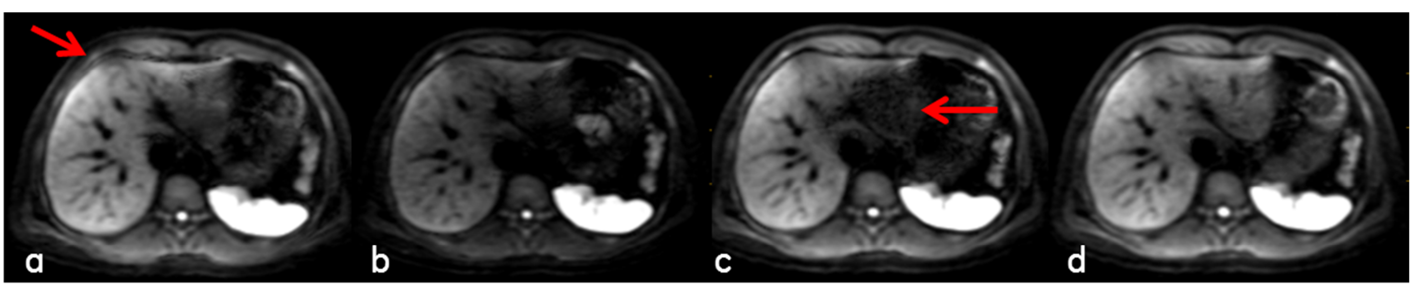

Fig. 1 Combined diffusion-weighted images obtained using conventional method for data acquired with a) SSE, b) DSE, c) SSE+HOEC. d) is the image calculated with the smart combination on data acquired with SSE+HOEC (as used in c). The arrow in a) points to the artifact due to geometric distortion/mis-registration. The arrow in c) points to the signal loss due to cardiac motion.

References 1. Li et al. abstract submitted to ISMRM 2012. 2. Stejskal et al. J Chem Phys 41:288, 1965. 3. Reese et al. MRM 49:177, 2003. 4. Xu et al. ISMRM 19:4564, 2011.