Physiological motion artifact correction in segmented DTI measurement of anesthetized non-human primates

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Introduction. Diffusion tensor imaging (DTI) is widely used to study white matter diseases and map fiber tracts in vivo [1]. However DTI is susceptible to any motion during scanning. Segmented EPI, which is often used to achieve higher spatial resolution tensor images for anesthetized non-human primate subjects, is especially vulnerable to inherent physiological motion. Motion results in corrupted images, and could therefore cause strong errors in fractional anisotropy and in vivo fiber tractography. The navigator echo method is the common solution to eliminate the EPI motion artifacts, along with image post-processing methods[2, 3,4], which are usually limited to single-shot EPI measurement. Uiug et al applied the reference phase correction for diffusion-weighted image [5]. With this method, the corrected image intensity is deviated from its original stage because all the phase information in both readout and phase-encoding directions from the one reference image is applied to others for the correction. In this study, we introduce a similar strategy but the optimal reference phase has the phase information of the phase-encoding direction only, and the intensity deviation of the corrected image, caused by the motion correction, is mitigated. And more, the reference image is varying with the different corrupted image when it is obtained from the adjacent non-corrupted images. This approach does not require additional data acquisition or pulse sequence modification. The results were demonstrated with anesthetized non-human primate subjects.

Methods. A rhesus monkey (6.5 kg) was anesthetized with ~1.5 % isoflurane and was placed in the sphinx position and immobilized with the custom-built holder. A chimpanzee (67 kg) was anesthetized with 10mg/kg propofol and was placed on its back with the head immobilization by cushions. End-tidal CO_2, inhaled CO_2, O_2 saturation, heart rate, respiration rate, and rectal temperature were monitored continuously.

DTI was acquired using a standard double-spin echo EPI sequence on a Siemens Trio 3T with 2-segment EPI, TR= 4000 ms, TE = 91ms, 30 directions with b = 0, 1000 s/mm^2, FOV = 12.8x12.8 cm for the rhesus with an extremity CP knee coil and 19.2x19.2 cm for the chimpanzee with Siemens CP head coil, data matrix = 64x64 (monkey) or 128x128 (chimp), slice thickness = 2.0 mm.

The corrupted images were identified by comparing the pixel intensity outside the parent image with the standard deviation of the image background. The adjacent image which had the minimal motion artifact was selected and the reference phase map was generated from the inverse FFT of the image in the phase-encoding direction only. If several scans were performed, the reference phase could be generated from the correspondent image in other scans as well. The reference phase was used to replace the defective phase in the correspondent corrupt images. Because the motion ghost appeared only in the phase-encoding direction, no correction was applied in the readout direction.

Results. Typical diffusion-weighted images before and after the motion correction of a rhesus monkey and a chimpanzee DTI are displayed in **Figure 1**. The corrupted images were corrected by the proposed algorithm and the artifacts and ghosts are reduced significantly. Especially the low SNR diffusion-weighted images from the chimpanzee (Figure 1(B)) was corrected successfully.

Discussion. DTI artifacts and ghosts result from the physiological motion of the anesthetized animals. Either Navigator Echo or post image processing can be implemented to correct the motion artifacts, but these methods require either sequence modification (for Navigator Echo) or acquisition of additional physiological data [4]. Moreover, most image post-processing methods works only for single-shot EPI and is invalidated in multi-shot EPI measurement. The severity of the artifacts is co-related with the amplitude of the physiological fluctuation. Meanwhile, the varying reference phase map will closely represent the phase of the corrupted image.

Ulug's method[5] applied the phase reference correction in both readout and phase-encoding directions, consequently the corrected image loses the image intensity information contributed from the varying phase term completely. By comparison, this situation is mitigated with one-direction phase reference correction.

Conclusions: this study demonstrates a robust correction algorithm for segmented DTI without the need for sequence modification or additional data acquisition. As illustrated in DTI measurements from anesthetized non-human primate subjects, this approach successfully recovers corrupted images and improves DTI results and quantification.

References: 1) Melhem et al, AJR 178:3-16, 2002. [2] Jiang et al, MRM, 47(4):818-22, 2004. [3] Weih et al, MAGMA, 16(6):277-83, 2004. [4]Le et al, MRM, 35:290-298. 5) Ulug et al, MRM, 34(3):476-80.

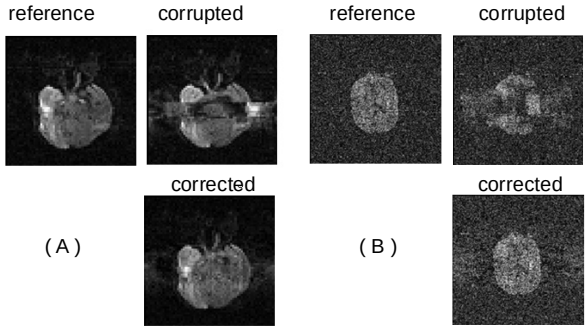

Figure 1 (A) Monkey DTI data of the reference image, corrupted images and motion corrected images. (B) Chimpanzee DTI data of the reference image, corrupted images and motion corrected images.