Diffusion Weighted Imaging of In-vivo heart with 2nd moment nulling diffusion gradient

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Purpose: Cardiac Diffusion-weighted imaging (DWI) has a potential clinical application on myocardial infarction visualization [1]. However, image quality is limited by additional signal loss by physiological motion. A bipolar shape diffusion gradient pulse which compensates a phase error caused by velocity term of motion is proved to attenuate the effect of cardiac motion on DWI with b-factor <= 400[2]. A motion compensation until acceleration term of motion (aMC) with 2nd moment nulling is expected to achieve higher b-factor(>=500) DWI but prolonged TE may cause SNR reduction. We investigated the feasibility of aMC-DWI combined with ECG triggering on 3.0T MR system with a high SNR cardiac coil.

Methods: The aMC, 2nd moment nulling, shape is shown as Fig.1. An ECG triggering and a respiratory navigator echo (RNAV) are combined on a 3.0T scanner. High SNR of 3.0T scanner and a multi-channel cardiac coil allows reducing the number of acquisitions to 3. As a fat suppression method, combined method of SPIR and SSGR (Slice Selection Gradient Reversal)[3] was employed. Cardiac DWI was performed in 5 healthy volunteers on a 3.0T Philips Achieva TX system. Scan parameters were: single shot SE-EPI, b=0, 500, 800 s/mm2, thickness/gap = 5/0 mm, 12 slices, FOV 350mm, 3 NSA, 2.5x2.5mm pixel size, SENSE factor 2.0, TE=71ms, TR=12beats. The optimum ECG Trigger delay (TD0) is determined with Balanced TFE cine scan images. Conventional mono polar gradient DWI (CONV) was also performed for comparison. TE for CONV scan =40ms. Three scans were performed with TD=TD0, TD0+100ms and TD-100ms for both aMC and CONV methods to observe robustness against TD change. ADC map was calculated from acquired DW images (b=0, 500 s/mm2). Written informed consent was obtained from all volunteers.

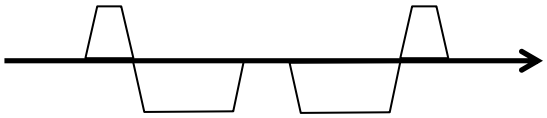

Fig. 1 aMC: 2nd moment nulling pulse

Results: Result images were visually rated. With aMC at b=500 s/mm2, 5 out of 5 subjects' myocardium were visualized, 3 with uniform signal intensity and 2 with visible non-uniformity. At b=800 s/mm2, 4 out of 4 subjects were visualized, 1 with uniform signal and 3 with visible non-uniformity. With CONV at b=500s/mm2, 3 of 5 subjects were visualized and 2 subjects showed no myocardial signal. At b=800 s/mm2, 2 of 4 subjects showed DWI images, one uniform and one with artificial signal loss, while 2 subjects showing no signal.
Average ADC value among subjects were 2.22 ± 0.41 x 10^{-3} mm2/s for aMC and 3.29 ± 1.01 x 10^{-3} mm2/s for conventional method.

Discussion & Conclusion: The proposed method, aMC + ECG, allows cardiac DWI on b=500 s/mm2 with uniform and robust image quality. On a few subjects, the cardiac DWI was possible even with conventional DWI. However, a small change of trigger delay results severe signal loss (Fig.2 upper row), in contrast to the robustness of aMC-DWI (Fig.2 bottom row).

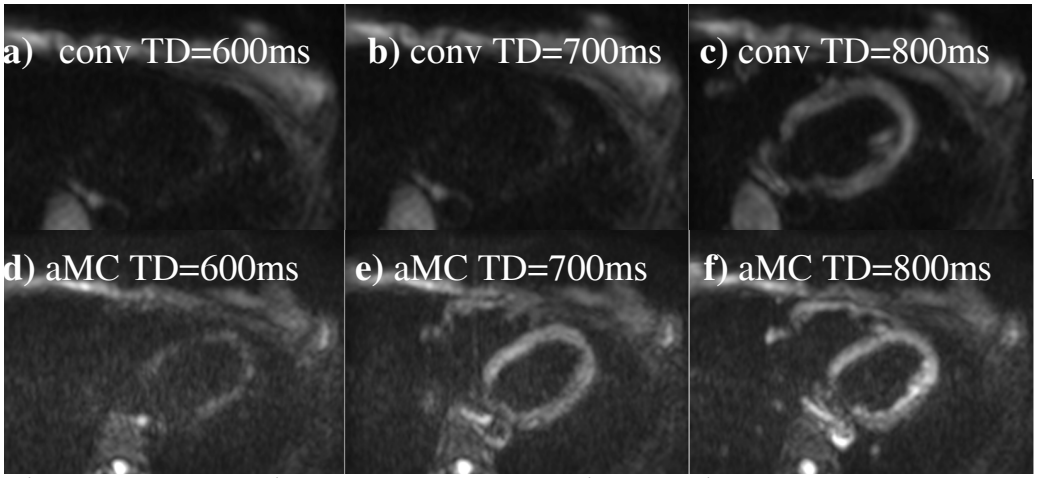

Fig. 2 b=800s/mm2 cardiac DWI. Upper row: DWI with conventional method. Bottom row: aMC-DWI. ECG triggering delays are a) & d) 600ms, b) & e) 700ms, c) & f) 800ms. Signal intensity is maintained in a wider range of trigger delay with aMC.

The scan time was short as 3-4 minutes. The aMC-DWI is expected to enable a cardiac DWI up to b=800 s/mm2 in a clinical level of robustness and a short scan time.

References: [1] Jean-Pierre Laissy,et.al, J. Magn. Reson. Imaging. 2013 Apr 5. doi: 10. 1002/jmri, [2] Gamper,U, et.al, MRM 57:331–337 (2007). [3] Horie,T et al. ISMRM 2009 e-poster #4035