Motion Induced Signal Non-Uniformity Correction with Asymmetric bipolar MPG on Liver DWI

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Body DWI has been proposed recently as a sensitive tumour detection method.

One of the major issues with abdominal DWI is signal loss in soft tissues. Recent study (1) showed that this is mainly due to cardiac pulsation. Voxel deformation due to cardiac motion combined with strong diffusion gradient pulse induces intra-voxel spin phase dispersion that causes signal loss in both left and right lobes of the liver. Using a pair of bipolar gradient pulses, it is possible to compensate for this loss (2). We refer to this as motion compensated motion-probing gradient (MC MPG) approach. However, MC MPG is detrimental for diffusion weighting compared to conventional MPG. To achieve the same b-factor, higher gradient amplitude is required for MC MPG. This leads to significant prolongation of the minimum TR due to gradient hardware limitation. In this study, we propose a new type of MPG formed as a hybrid of conventional unipolar MPG and MC MPG(HybMC MPG) to shorten the minimum TE/TR. With this method, significant reduction of signal non-uniformity of DWI is possible while total scan time remains within clinically acceptable limits.

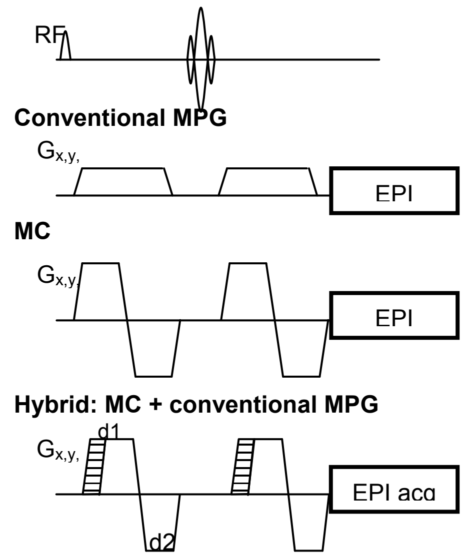

Fig.1.MPG pulse shape of conventional, MC and Hybrid (top to bottom)

Methods:

MC MPG is a pair of bipolar gradient pulses (fig.1 middle) equivalent to standard 1-2-1 flow compensation gradient scheme. A unipolar gradient pulse is added in front of both bipolar pulses (fig.1 bottom). b-value is given by following formula:

$$b = \gamma^2 G^2 \times \{(d_1^3 + d_2^3)\cdot\frac{2}{3} + \zeta\cdot(d_1^2 + d_2^2)\cdot 4 - \zeta\cdot d_1\cdot d_2\cdot 20 + \zeta^2\cdot(d_1 + d_2)\cdot\frac{23}{6} + \zeta^3\cdot\frac{46}{15} + d_i\cdot(d_1 - d_2)^2\}$$

where d1 and d2 are durations of first and second pulse plateau, and ζ is slope duration.

The efficiency of b-factor is determined by the difference between d1 and d2. However, motion induced phase compensation will be imperfect. For respiratory motion, we used TRON (Tracking Only Navigator) compensation method (3). The method acquires navigator echo on a lung-liver boundary to estimates diaphragm shift. The imaging slice location is adjusted in real time with the estimated shift.

Abdominal DWI was performed in 5 healthy volunteers on a 1.5T Philips Achieva system. Scan parameters were: single shot SE-EPI, thickness/gap = 5/0 mm, 36 slices, b=0, 500, FOV 300mm, 5 NSA, 112x110 matrix, SPIR fat suppression. For HybMC MPG, d1 – d2 was set to 3ms. Each volunteer was scanned with two DWI methods: 1) conventional MPG and respiratory triggering (RT), TE = 57ms 2) HybMC MPG with TRON, TE = 63ms. To estimate the effect on image quality with HybMC approach, we measured ADC values in the left and right liver lobes and computed the their ratio.

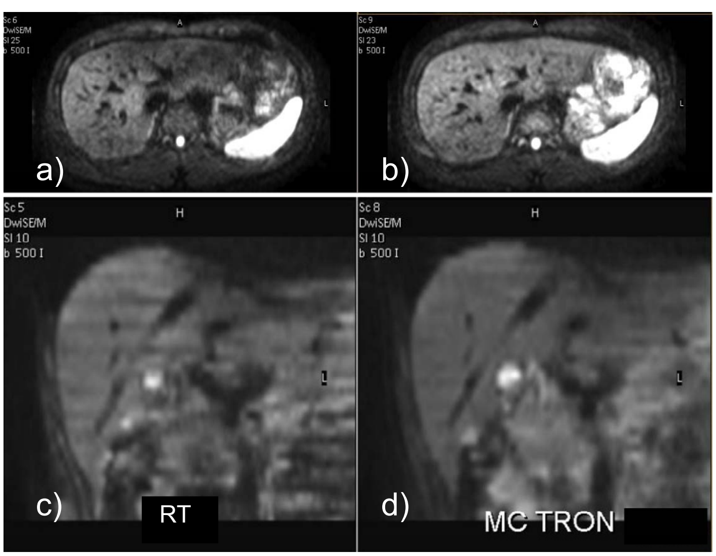

Fig.2 a,c) MPG with RT. b,d) HybMC MPG with TRON

	SNR	ADC Left	ADC Right	ADC L/R
Conv. RT	14.7	2.70±0.47	1.62±0.14	1.67
Hy MC	14.1	1.83±0.27	1.40±0.14	1.31

Results:

Axial images and their coronal reformat are shown in fig.2. Severe signal non-uniformity can be seen on the left side of the liver with conventional MPG, but improved with hybrid MC. Coronal image obtained with conventional method suffers from stripe artefacts. These artefacts are significantly suppressed with hybrid MC.

Total scan time was 5:24 with conventional approach and 5:55 with HyMC TRON, which is only 10% slower compared to conventional RT.

Discussion:

Severe signal inhomogeneity in the whole liver is present when using conventional MPG approach with respiratory triggering. With Hybrid MC MPG it is possible to considerably improve image quality. ADC increases by 67% compared to conventional MPG on left lobe of the liver but 31% with HybMC MPG. HybMC reduces the effect of cardiac motion, but not completely.

Conclusion:

Image quality of abdominal DWI is improved with HybMC TRON by signal inhomogeneity suppression with small cost of scan time prolongation.

References: 1) T. C. Kwee, et al. (2009) . Magma 22 (5) 319-325, 2) Ogino, T. et al, ISMRM-ESMRMB Joint Meeting 2009 4068. 3) Ivancevic, M. K., et al. JMRI 30 (5) 1027-1033