Uniform and reproducible ADC measurement on liver

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Introduction: Body diffusion weighted image (DWI) has been proposed recently as a sensitive tumour detection method. Apparent Diffusion Constant (ADC) is promising as an index for early cancer therapy response. One of the major issues with abdominal DWI is signal loss that notably appears in the left lobe of the liver due to cardiac pulsation. Another major issue is image blur caused by respiratory motion. On conventional MR imaging, triggering techniques (cardiac or respiratory) are widely used to eliminate motion effects. However, due to severe scan time prolongation, only respiratory triggering (RT) DWI is performed in clinical studies. A recent study [1] shows that cardiac motion affects not only the left lobe but also the right lobe, which may cause artificially elevated value and poor reproducibility of the measured ADC. The purpose of this study is to demonstrate a method that Compensates both Respiratory and Cardiac (CoRC) motion effects with clinically feasible scan time.

Methods: For above purpose, peripheral pulse unit (PPU) triggering [2], double bipolar diffusion (DBD) gradient pulse (Fig.1)[3], breath holding (BH) and slice tracking with respiratory navigator (RNAV) echo method [4] are all implemented on a 3.0T scanner. PPU is preferred to ECG due to ease of use. After certain delay time (TD), RNAV is performed followed by two DW-SE-EPI slices. DBD gradient can attenuate motion induced signal loss by compensating phase shift due to motion [3]. One DWI scan is separated into 3 BH scans. Normally, to obtain one DWI image, three scans which three orthogonal directions of diffusion gradients are performed. In this proposed method, the three scans are executed as three separated BH scans. RNAV slice tracking is employed to correct location shift between separated BH scans. High SNR of 3.0T scanner allows reducing the number of acquisitions to 1. As a fat suppression method, combined method of SPIR and SSGR (Slice Selection Gradient Reversal)[5] was employed. Abdominal DWI was performed in 7 healthy volunteers on a 3.0T Philips Achieva TX system. Scan parameters were: single shot SE-EPI, thickness/gap = 5/3 mm, 20 slices, FOV 350mm, 1 NSA, 112x88 matrix, SENSE factor 2.0, TE=57.6ms, TR=10beats. PPU TD=400ms. Conventional RT-DWI was also performed for comparison. TE for RT scan =47.6ms and trigger delay = 600ms. A set of scans with two methods was repeated 5 times for all 7 subjects. ADC map was calculated from acquired DW images. 5 small ROIs were set among 5 slices in both left and right lobe of liver. Mean and SD values among 5 ROIs are measured. Left and right lobes of liver ADCs are compared for each subject and each method (CoRC, RT).

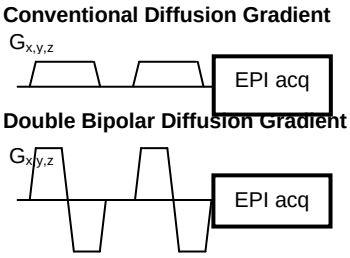

Fig.1 Gradient scheme

Results: SDs of ADC for 5 repeated scans are compared for each subject (Table 1) with F-test to observe intra-subject reproducibility. On all subjects, SD of CoRC is smaller than RT. For 3 of 7 subjects, the difference was statistically significant. Mean ADCs among 7 subjects with two methods are compared by t-test (Table 2, Fig. 2). CoRC ADCs were significantly smaller than RT ADC. With CoRC, left and right lobes ADCs were apparently equal. With RT, left lobe ADC was significantly larger than right lobe by a factor of 1.7.

Table 1. SD among 5 repeats comparison between two methods

Subject	1	2	3	4	5	6	7
RT	0.223	0.371	0.341	0.366	0.349	0.340	0.443
CoRC	0.148	0.071	0.136	0.051	0.162	0.153	0.067
F	0.442	0.037	0.160	0.020	0.215	0.203	0.023
p	0.448	0.037	0.103	0.002	0.165	0.151	0.003

SD of left lobe of liver ADC with CoRC is smaller than with RT.

Table 2. Mean and SD of ADC: 7 subjects x 5 repeats

	Left ADC			Right ADC			L vs R
Method	Mean	SD	P	Mean	SD	p	p
RT	2.72	0.53	4.9E-18	1.58	0.22	3.5E-07	2.30E-15
CoRC	1.28	0.12		1.31	0.17		0.41
F test		0.05	7.6E-14		0.57	0.11	

ADC difference between RT and CoRC is significant on both left and right lobe of liver. Left-Right ADCs are apparently equal for CoRC.

Discussion: Intra- and inter-subject ADC reproducibility is improved by combining multiple compensation methods. Left/Right difference was notably reduced and a more uniform ADC map was obtained (Fig. 3). ADC on right lobe with RT is significantly larger than that with CoRC. This result is consistent with the prior study in which cardiac pulsation could cause DWI signal attenuaton even on the right lobe [1]. Thus we infer that mainly cardiac motion compensation causes signal intensity increase and lower but consistent ADC value. With respect to total scan time, one CoRC scan consists of 4 BH and the nominal BH duration is 10sec (10beats / 60 bpm) for 20 slices. This suggests that four 15sec breath hold scans, which is clinically feasible, could cover the whole liver by 30 slices.

Conclusion: The Proposed method improves liver ADC measurement in clinically feasible scan time. Evaluation of effect by BH and slice tracking on respiratory motion artefact will be future study.

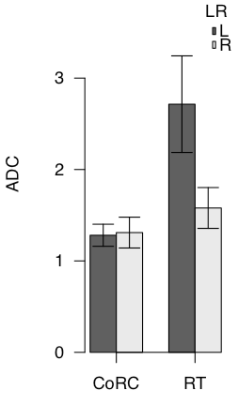

Fig.2 Left/Right ADC

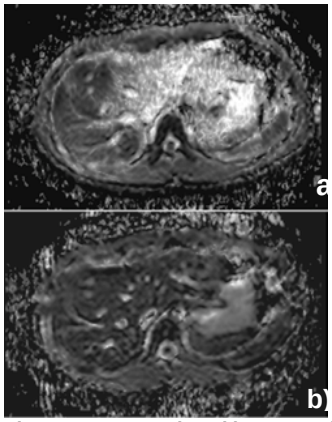

Fig.3 ADC maps: a) RT b) CoRC Left lobe ADC is artificially elevated on RT-The CoRC map is more homogeneous.

References: [1] T. C. Kwee, et al. (2009). Magma 22 (5) 319-325, [2] Ogino,T, et al. ISMRM 2011 traditional poster #839, [3] Ogino,T, et al. ISMRM 2010 e-poster #4719. [4] Ivancevic, M. K., et al. JMRI 30 (5) 1027-1033. [5] Horie,T et al. ISMRM 2009 e-poster #4035