Improved Abdominal Diffusion Weighted Imaging at 3T using Optimized Shinnar-Le Roux Adiabatic Radiofrequency Pulses

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Target audience: Physicists and radiologists interested in the development and application of improved abdominal diffusion weighted imaging.

Introduction: Diffusion weighted imaging (DWI) of the abdomen has important applications as a diagnostic tool for diffuse and focal diseases [1]. In this regard, 3T platforms may offer higher signal to noise ratio (SNR) leading to improved accuracy when compared to 1.5T; however previous studies have reported limited gains [2]. A source of poor performance at 3T is the increased inhomogeneity of the radiofrequency (RF) field, or B_1. The purpose of this study is to improve abdominal DWI at 3T by using adiabatic pulses, which offer improved immunity to B_1 inhomogeneity, in a Twice Refocused Adiabatic Spin Echo (TRASE) [3] or a Matched-phase Adiabatic Spin Echo (MASE). We hypothesize that adiabatic pulses will lead to increased SNR and more homogeneous signal intensity in abdominal organs, as well as improved visualization of diffusion metrics compared to conventional DWI using linear phase pulses.

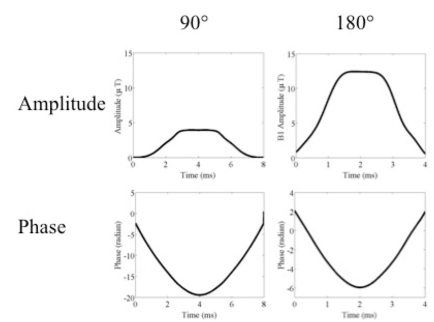

***Figure 1**: RF Pulses used in the adiabatic DWI sequences (TRASE and MASE). Left: adiabatic refocusing pulse, right: matched-phase excitation pulse.*

Methods: The adiabatic Shinnar-Le Roux (SLR) algorithm [2] was used to design an efficient adiabatic refocusing pulse, with a 4 ms duration, 1.32 kHz spectral bandwidth and 12.4 µT peak RF amplitude at adiabatic threshold (Figure 1). This pulse was used as a refocusing pulse in a single-refocused MASE or twice-refocused TRASE DWI sequence with single shot echo planar imaging readout. For the MASE sequence, a matched-phase 90° excitation pulse (8 ms duration) was derived from the beta squared polynomial of the adiabatic 180° [3] in order to correct for the nonlinear phase induced by the adiabatic refocusing pulse. MR imaging was performed on a healthy volunteer at 3T (Magnetom Skyra, Siemens Healthcare, Erlangen, Germany) after informed consent was obtained. TRASE and MASE acquisitions were compared with Twice Refocused Spin Echo (TRSE) and Stejskal-Tanner (ST) conventional DWI. 40 slices were sampled in axial orientation, covering the upper abdomen, during shallow free breathing. Imaging parameters were: resolution 2.3 x 2.3 mm^2, slice thickness 7 mm, bandwidth 1200 Hz/pixel, parallel imaging R=3 (GRAPPA), partial Fourier 6/8. 2 b-values were sampled (0 and 800 s/mm^2) in 3 orthogonal directions to yield an estimate of the diffusion trace. Sequence-specific parameters are given in Table 1. A pixelwise map of the apparent diffusion coefficient (ADC) was computed using the ADCmap plugin in Osirix (Pixmeo, Switzerland). SNR was measured on b=800 s/mm^2 trace images, as the ratio between the signal intensity in an ROI located in the right posterior lobe of the liver, divided by the standard deviation of the signal of an ROI located in an air region. Specific absorption rate (SAR) was recorded for each acquisition.

Results: All acquisitions performed within SAR limits, even when using adiabatic refocusing pulses (Table 1). As shown in Table 1, a 130% increase in SNR was observed for TRASE when compared to TRSE and a 77% increase in SNR was observed for MASE when compared to ST. In central regions suffering from B_1-induced signal loss on TRSE and ST acquisitions, using adiabatic pulses resulted in recovered signal intensity and increased ADC map quality (Figure 2).

	TE (ms)	TR (s)	SAR (W/kg)	Liver SNR
TRSE	70	3.8	1.23	7.3
TRASE	70	4.3	1.57	17.0
ST	55	2.9	1.37	15.7
MASE	57	3.1	1.83	27.9

***Table 1**: Sequence parameters, SAR and SNR for conventional and adiabatic DWI acquisitions.*

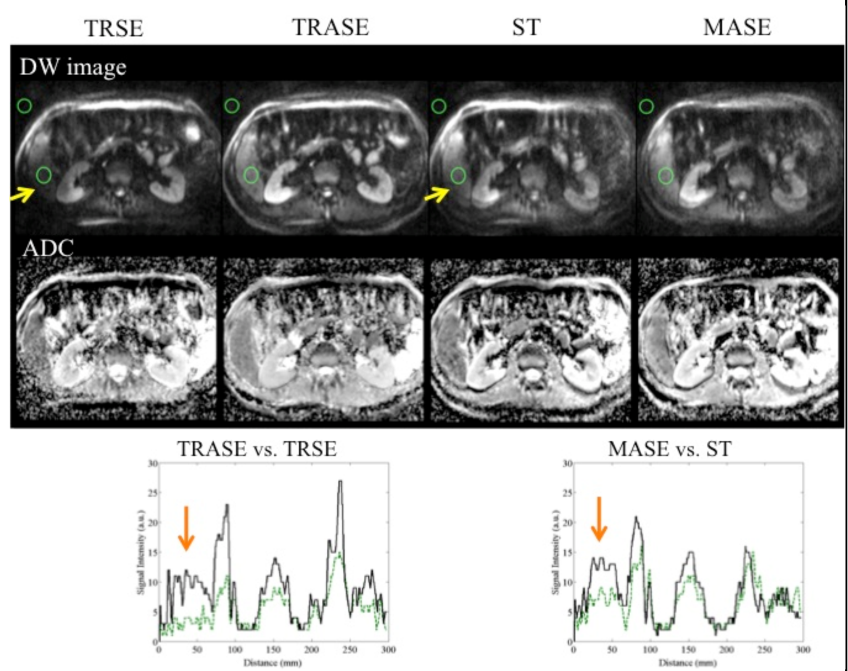

***Figure 2**: Abdominal DWI acquired in a healthy volunteer at 3T, comparing conventional DWI (TRSE and ST) with adiabatic DWI approaches developed in this work (TRASE and MASE). Top: DW image (b=800). Middle: ADC maps. Bottom: signal intensity profiles along a horizontal line (solid black: adiabatic DWI, dotted green: conventional DWI). Yellow arrows point to signal loss in the liver, which appears to be more severe for conventional DWI (TRSE and ST) than for adiabatic DWI (TRASE and MASE). Orange arrows point to signal increase observed in the liver for TRASE and MASE signal intensity profiles. Green circles represent ROIs used for SNR estimation.*

Discussion and Conclusion: We have proposed a novel approach for spin-echo DWI acquisition in the abdomen at 3T, using adiabatic refocusing pulses that are more robust to B_1 inhomogeneity than conventional pulses. Our approach can be used for twice- or single-refocused DWI. TRASE and MASE lead to improved signal homogeneity in the upper abdomen, along with increased SNR and improved ADC map quality, while remaining within SAR limits. SNR gains were higher for TRASE vs. TRSE than for MASE vs. ST acquisitions, because the effect of B_1 inhomogeneity is more severe when using 2 refocusing pulses as is the case in TRSE. Although overall SNR is highest when using MASE, TRASE images achieve sharpest depiction of anatomy due to greater immunity to eddy current effects, resulting in less blurring. Therefore both adiabatic DWI sequences presented here offer advantages over conventional DWI and optimal sequence choice will be application dependent. In conclusion, using adiabatic pulses in DWI acquisitions leads to higher data quality for 3T abdominal DWI, and may allow for increased diagnostic accuracy. Future work includes evaluating this new approach for lesion detection as well as for advanced applications such as abdominal diffusion tensor imaging and intravoxel incoherent motion [6] at 3T.

References:

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