Continuously moving table whole-body diffusion weighted imaging using an adaptive gradient reversal technique

Yeji Han[1], Chang Heun Oh[1], and HyunWook Park[1]
[1]*Department of Electrical Engineering, KAIST, Daejeon, Daejeon, Korea*

Introduction

Although whole-body diffusion-weighted imaging (wbDWI) is generally performed using the multistation approach, the continuously moving table (CMT) approach can be used as an alternative to generate images with more homogeneous temporal and spatial continuities [1]. While short tau inversion recovery (STIR) technique is an appropriate choice for fat and background signal suppression in 1.5T MRI systems [1,2], a more efficient fat-suppression technique is required for the CMT-wbDWI in 3T MRI. In this abstract, an adaptive gradient reversal technique is proposed for the CMT-wbDWI method, where the opposite polarities of slice selection gradients are used for 90° and 180° RF pulses with an RF pulse adaptation.

Methods

The gradient reversal (GR) algorithm [3,4] generates a spin-echo signal from on-resonance tissues only, by applying the slice selection gradient for the 180° RF pulse in the opposite polarity to the slice selection gradient of the 90° RF pulse. In the CMT acquisition case, the basic gradient reversal technique is inappropriate for sufficient fat suppression because the patient table is constantly moving during the scan. More specifically, the spins in the slice excited by the 90° RF pulse have shifted away by an amount determined by the relation between the table speed and the echo time (= $v \times t_{TE}/2$, where v is the table speed and t_{TE} is the echo time), when the 180° RF pulse is applied. Thus, using the 180° RF pulse with the same frequency as the 90° RF pulse may result in a mismatch of excitation and refocusing slices as illustrated in Fig. 1. In the proposed adaptive GR method, the frequency of the 180° RF pulse is adjusted to $f_c - \gamma G_z/2\pi \times t_{TE}/2 \times v$, where f_c is the frequency of the 90° RF pulse, γ is the gyromagnetic ratio, and G_z is the amplitude of the slice selection gradient. In this way, the 90° and 180° RF pulses can excite and refocus the identical slice, even with the table motion. In the proposed CMT-wbDWI, the adaptive GR method is implemented for the single-shot DW echo-planar imaging (EPI) sequence.

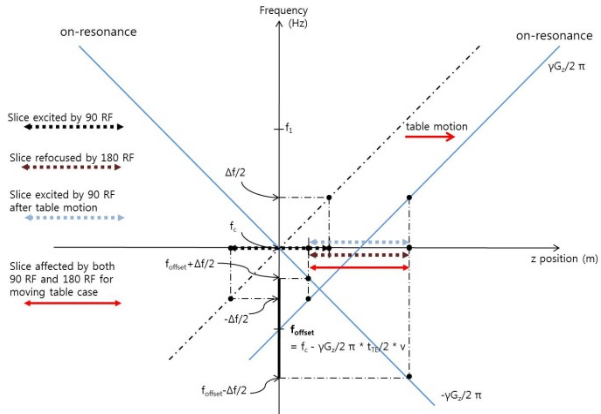

Fig.1. The proposed adaptive gradient reversal algorithm

Experiment Results

To verify the performance of the adaptive GR technique, CMT-wbDWI was acquired from a healthy male volunteer with the single-shot spin-echo DWI sequence at a 3T Verio system (Siemens, Erlangen) using the following parameters: TR = 2000 ms, TE = 75 mm, b = 150 s/mm^2, matrix size = 128 × 96, axial FOV = 380 × 285 mm^2, number of slices = 200, slice thickness = 6 mm, bandwidth = 2242 Hz/px, number of averages = 1, thereby generating images with an in-plane resolution of 2.9 × 2.9 mm^2 and covering a longitudinal FOV of 1200 mm in a total acquisition time of 6 min 40s (= 2000 ms × 200 slices). For whole-body coverage, body matrix coils were used. As a comparison, CMT-wbDWI was also performed with fat saturation (FatSat) and STIR (TI = 250 ms), both of which used the same imaging parameters as the adaptive GR technique. The table was moving with a constant speed of 3mm/s during the scan. The acquired DW images with different fat suppression techniques in CMT cases are presented in Fig. 2. As the figures demonstrate, the GR method produces fat-suppressed images with high accuracy compared with other fat suppression techniques. Fig. 3 shows inverted grayscale maximum intensity projection (MIP) images generated from images acquired with different fat suppression techniques. As demonstrated by Fig. 3, insufficiently suppressed fat signals generate artifacts in the MIP images, disturbing an accurate diagnosis.

Discussion

The GR technique is an effective approach for suppressing fat signals in the spin-echo based sequences because it does not employ additional RF pulses, thus preventing increased specific absorption rate (SAR) or an increased acquisition time. In a CMT sequence, however, the patient table, i.e. the target slice, is continuously moving and the conventional GR does not fully generate on-resonance signals. Thus, the proposed RF frequency adaptation can be useful to carefully match the excitation and refocusing slices. Moreover, the proposed method is especially efficient in 3T MRI because the conventional fat suppression techniques such as FatSat and STIR are not operating as effectively as in the lower field MRI systems.

Conclusion

The CMT approach is an efficient method of acquiring wbDWI as it provides high-quality images without additional shimming because the images are continuously acquired at the isocenter. With the proposed adaptive GR technique, CMT-wbDWI can be more efficiently used for whole-body screening.

References

1. Han Y et al., Whole-body diffusion-weighted imaging with a continuously moving table acquisition method: Preliminary results, MRM 2011, 65(6):1557-1563.
2. Takahara T. et al. Diffusion weighted whole body imaging with background body signal suppression (DWIBS): technical improvement using free breathing, STIR and high resolution 3D display, Radiat Med 2004; 22:275-282. 3. Park HW et al., Gradient reversal technique and its applications to chemical-shift-related NMR imaging. MRM 1987, 4(6):526-36. 4. Takahara T. et al. Fat suppression with slice-selection gradient reversal (SSGR) revisited, ISMRM 2009.

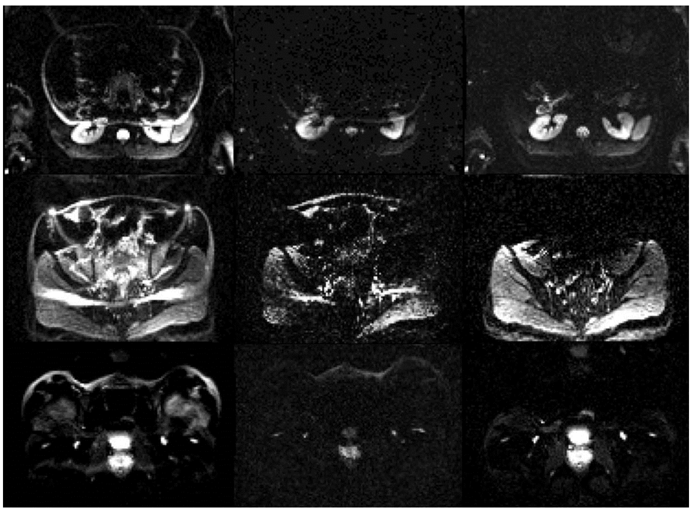

Fig.2. DW images of three different slices acquired with FatSat (left), STIR (middle), and the proposed fat suppression (right) methods.

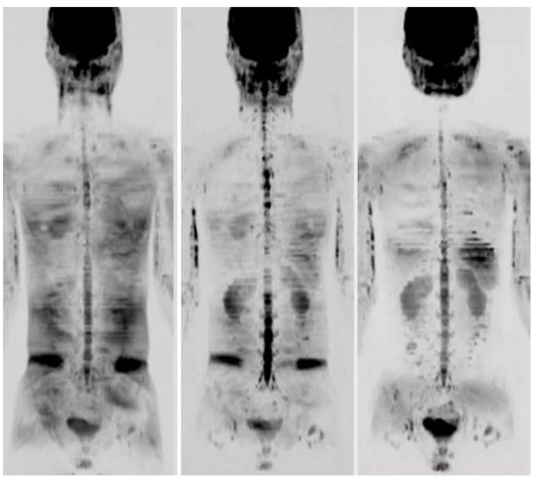

Fig.3. Coronal view of the inverted grayscale MIP images acquired with FatSat (left), STIR (middle), and the proposed fat suppression (right) methods.