Fat suppression for continuously moving table whole-body diffusion-weighted imaging using the gradient reversal technique

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Introduction

Whole-body diffusion-weighted imaging (wbDWI) can be beneficial for patient screening or treatment monitoring because it has a superior disease contrast. Although wbDWI is generally performed using the multistation approach, a recent work [1] has demonstrated that the continuously moving table (CMT) approach can be used to generate images with more homogeneity in terms of temporal and spatial discontinuities. In [1], DW images were acquired with short tau inversion recovery (STIR) technique so that unnecessary fat signal could be suppressed. Although the performance of STIR was relatively satisfactory, remains of the fat signal could still be observed in many image slices as marked with arrows in Fig.1. Thus, a more effective fat suppression method is required to improve the CMT-wbDWI. Recently, several reports have confirmed that the gradient reversal (GR) algorithm, first reported more than 20 years ago [2], can be more efficient in multistation whole-body imaging than many other fat suppression techniques [3,4]. In this abstract, we propose to use the GR algorithm for CMT sequences and analyze why the GR algorithm can provide improved fat suppression results in the images acquired with the CMT sequences.

Fig 1. A transaxial image acquired with the CMT-wbDWI sequence. Artifacts resulting from fat are marked with arrows.

Experimental Results

The GR method can be implemented for multislice acquisitions as illustrated by the sequence diagram in Fig. 2, where the reversed gradient (solid line) is used instead of a normal selection gradient (dotted line). For multislice expansion of the GR technique, the center frequencies of the excitation RF pulse ($f_{c,90}$) and refocusing RF pulse ($f_{c,180}$) for each slice should have an alternating polarity, i.e. $f_{c,180}=-f_{c,90}$. Then, as in a conventional SE sequence, $f_{c,90}$ can be determined with respect to the desired slice positions. To verify the performance of the GR technique, the multislice GR-SE was applied to a custom-made phantom which was filled with olive oil, soybean oil, methanol, and water, as shown in Fig.3 (left) and the images were acquired at a 3T MRI system (ISOL technology, Korea) using the following parameters: matrix size = 256×256, number of slices = 10, slice thickness=4mm, axial FOV=256×256mm^2. TR and TE of 1000ms and 45ms were used to follow the values suggested by our previous work [1]. The images acquired with the proposed GR method are shown in Fig.3. As the figures demonstrate, the GR method produces fat-suppressed images with high accuracy.

Fig 2. The multislice GR sequence diagram.

Discussion

As shown in Fig.1, the STIR technique works less efficiently for the CMT approach than for the multistation approach and the reason can be explained using the illustration shown in Fig.4. In a CMT sequence, the patient table, i.e. the target slice, is continuously moving. Thus, the slice which experiences the inversion pulse moves away from the imaging region and only a part of the signal contributing to the final image comes from the region which is affected by the inversion pulse (marked as gray area in Fig.4). In our previous work [1], a table speed of 3.5mm/s for a slice thickness of 7mm was suggested as a suitable value for wbDWI measurement. Knowing that the inversion time (TI) and TE are ~180ms/70ms in 1.5T MRI, and ~250ms/45ms in 3.0T MRI, the amount which moves away after the inversion pulse can be calculated as follows: For TI/TE of 180ms/70ms in 1.5T, the region that moved away from the target imaging region after the inversion pulse is 0.62mm (=(180ms+35ms)×3.5mm/s) at the time of refocusing RF, thus about 91% of the signal comes from the fat suppressed region. For TI/TE of 250ms/45ms in 3T, it is more increased to 0.95mm (=(250ms+22.5ms)×3.5mm/s), so that only 86% of the signal is fat suppressed. Thus, the fat suppression cannot function as intended, leaving signals originating from fat as shown in Fig.1. When the GR technique is used instead, the time between the excitation and refocusing pulses is the only factor that influences the effective slice for fat suppression. Since the unaffected slice thickness is only 0.122mm (=35ms×3.5mm/s) and 0.078mm (=22.5ms×3.5mm/s) in 1.5T and 3T, respectively, nearly 99% of the signal comes from the fat-suppressed region.

Conclusion

It is beneficial to use the GR method for fat suppression because it does not introduce additional scan time or increased SAR. Since the CMT technique used with STIR can produce fat-related artifacts as the slice influenced by the inversion pulse moves away from the isocenter, the GR method is even more recommended for the CMT approach. Particularly for the CMT-wbDWI imaging, the improved fat suppression can substantially improve general image quality.

Reference

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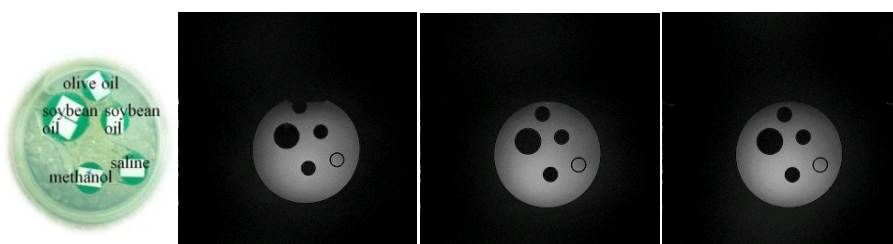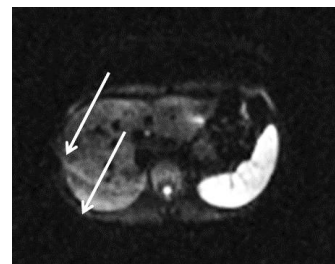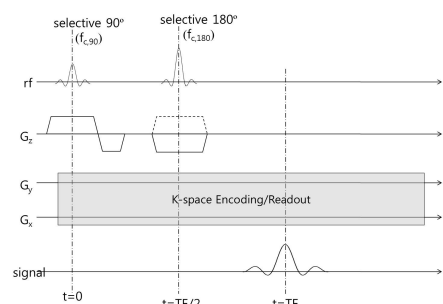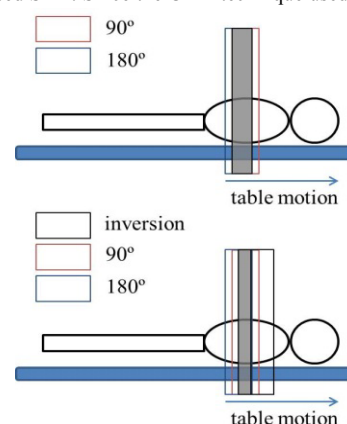
Fig 4. Illustration of the effective slice in the GR (top) and STIR (bottom) methods. The slice affected by each selective RF pulse is outlined by red (90° excitation), blue (180° refocusing) and black (inversion) boxes. Gray regions show the effective slice thickness.

Fig 3. Fat suppressed images (right) acquired using the GR technique with a custom-made phantom (left).