Fat Suppression Using the Gradient Reversal Technique for Continuously-Moving-Table Whole-Body MRI: A Comparative Study

Yeji Han[1], Yoojin Lee[1], Dong Chan Kim[1], Joonsoo Kim[1], and HyunWook Park[1]

[1]*Department of Electrical Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Daejeon, Korea*

Introduction

Continuously moving table (CMT) MRI is an efficient whole-body (wb) imaging technique for screening-type applications, which provides spatially and temporally continuous images [1,2]. However, CMT-MRI has to pay careful attention to fat suppression because the rationale behind the conventional fat suppression approaches, including short tau inversion recovery (STIR) and fat saturation, is not applicable to the CMT cases. For example, remains of the fat signal could still be observed in many image slices when STIR was used for CMT whole-body diffusion weighted imaging (wbDWI) [1]. Thus, a more effective fat suppression technique is needed to improve CMT-wbMRI. Recently, several reports have confirmed that the gradient reversal (GR) technique [3] shows efficiency in stationary (or multistation) whole-body imaging [4]. In this abstract, we propose an expansion of the GR technique for CMT sequences and compare with other fat suppression techniques to show that the GR algorithm can improve fat suppression.

Experiments

The GR method was implemented for CMT-SE-EPI sequence as illustrated in Fig. 1, where the reversed gradient (solid line) was used instead of a normal selection gradient (dotted line). By using the GR technique in the CMT condition, SE-EPI images can be acquired while successfully suppressing signals from fat. To verify the performance of the GR technique in CMT, images were acquired from a male volunteer using the SE-EPI with GR sequence at a 3T Verio system (Siemens, Erlangen) with the following parameters: TR/TE = 2000ms/60ms (table speed = 2.5mm/s) and 350ms/60ms (table speed = 14mm/s), TI = 220ms, matrix size = 128×96, number of slices = 300 (covering a longitudinal FOV of 1.5m), slice thickness=5mm, axial FOV=380×285mm^2. CMT SE-EPI was also performed with fat saturation (FatSat) and STIR as a comparison study. In addition, a set of images was acquired while simultaneously applying fat saturation and the GR technique. The acquired images are shown in Figs. 2, 3 and 4. As the figures demonstrate, the GR method produces satisfactory fat suppression results for CMT.

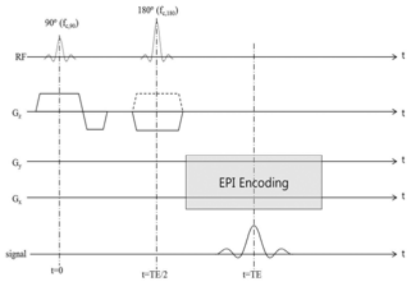

Fig 1. The multislice GR sequence diagram.

Results and Discussion

As shown in Fig.2, various fat suppression techniques provided similar fat suppression results in the brain regions, where the quantity of fat signal is rather moderate compared with other body regions. While fat suppression is less problematic for brain imaging, it can significantly deteriorate image quality in body. As presented in Fig.3, insufficient fat suppression caused severe degradation of image quality in upper thighs, as FatSat and STIR did not fully suppress fat signals due to the table motion. In a CMT sequence, the patient table, i.e. the target slice, is continuously moving and the slice which experiences the inversion pulse of STIR moves away from the imaging region. Thus, only a part of the signal that contributes to the final image is suppressed by the inversion pulse. For STIR, the amount of displacement after the inversion pulse can be calculated as (TI+TE/2)×table speed. Thus, in this experiment, about 87% of the signal (due to 0.0625mm displacement) comes from the fat suppressed region for the table speed of 2.5mm/s, whereas only 30% of the signal (due to 3.5mm displacement) is from the fat suppressed region for the table speed of 14mm/s. In case of FatSat, it cannot show satisfactory suppression results because the RF pulse for fat saturation cannot fully cover the fat signal due to pitch broadening in the CMT condition. Thus, the fat suppression cannot function as intended, leaving signals from fat (Figs.3 and 4), and this becomes worse as the table moves faster (Fig.4). When the GR technique is used, however, 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 (calculated as TE/2×table speed) is only 0.075mm (for 2.5mm/s) and 0.42mm (for 14mm/s) for GR method, 98% and 90% of the signal comes from the fat-suppressed region, respectively. Moreover, when GR is used in combination with FatSat, fat is more effectively suppressed as the GR and FatSat methods complement each other. As a result, images acquired with GR or GR in combination with FatSat have shown improvement in fat suppression quality for both low and high table speeds as illustrated in Figs.3 and 4.

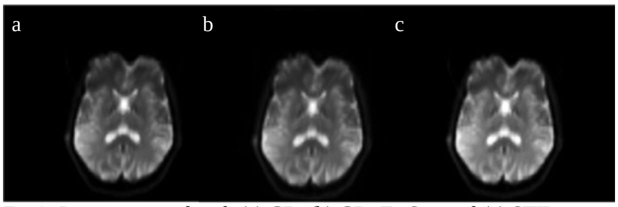

Fig.2. Image acquired with (a) GR, (b) GR+FatSat, and (c) STIR.

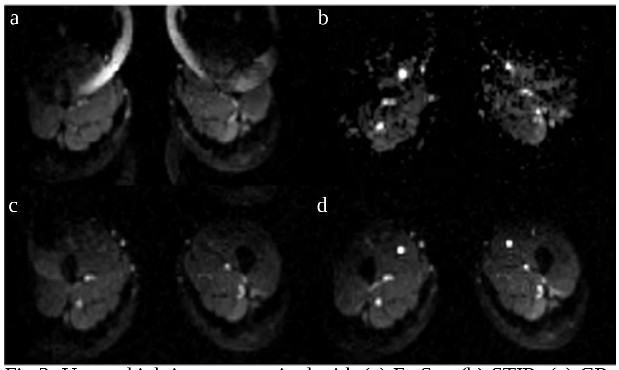

Fig.3. Upper thigh images acquired with (a) FatSat, (b) STIR, (c) GR, (d) GR+FatSat using a table speed of 2.5mm/s .

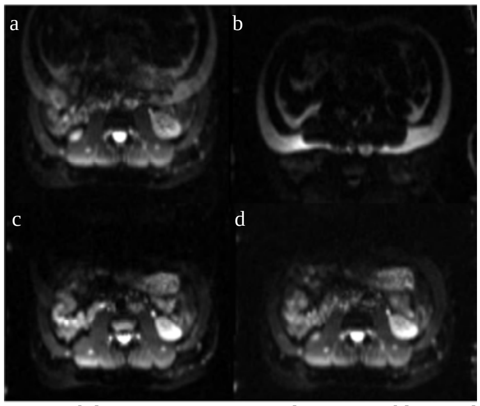

Fig.4. Abdomen images acquired using a table speed of 14mm/s with (a) FatSat, (b) STIR, (c) GR, and (d) GR+FatSat.

Conclusion

The GR method is a simple and efficient fat suppression technique which is easy to implement. Since STIR and FatSat techniques may produce remains of fat-related artifacts in the CMT cases as demonstrated by the experiments, the GR method is even more recommended for the CMT approach. Another advantage of the GR method is that it can be freely combined with other fat suppression method as it does not require additional scan time or increased SAR. Thus, it can be used independently or in combination with other fat suppression techniques for CMT whole-body imaging, such as CMT-wbDWI, to improve fat suppression, thereby improving the general image quality.

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] Bornert P et al., Principles of whole-body continuously-moving-table MRI, JMRI 2008, 28:1-12. [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.