Fat suppression with double off-resonance RF pulses for musculoskeletal imaging at 3.0T

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Target Audience

Researchers and clinicians with interest in acquiring musculoskeletal images with sufficiently suppressed fat signal in the presence of the main field inhomogeneity

Purpose

In musculoskeletal MR imaging, fat suppression is an important factor that contributes to the visibility of bone-marrow lesions and soft-tissue masses, improves the CNR in MR arthrography, and prevents chemical shift artifacts[1]. Compared to the lower field strengths, 3T musculoskeletal MR imaging is more delicately affected by the various types of fat-suppression techniques such as chemical shift (spectral) selective (CHESS) fat saturation, short inversion time inversion recovery (STIR), spectral adiabatic inversion recovery and spectral attenuated inversion recovery (SPAIR), and the Dixon techniques. While these techniques provide images with relatively satisfactory fat suppression results, the actual performance is unduly dependent on the main field homogeneity. Consequently, as the region-of-interest (ROI) moves farther away from the isocenter of the magnet at 3T, the fat suppression is less satisfactorily performed. Thus, a technique based on two off-resonance RF pulses is proposed in this study to provide a fat suppression technique that is less dependent on the main field homogeneity.

Methods

Instead of the conventional fat saturation, where a single off-resonance RF pulse is applied as a preparation pulse prior to the employed routine imaging sequence, the proposed method uses double off-resonance RF pulses as illustrated in Fig. 1. By applying double off-resonance $\alpha_x - \alpha_{x+180^\circ}$ RF pulses, off-resonance components such as fat are prevented from producing signals. When a single off-resonance RF pulse (e.g. fat saturation RF pulse) is used to disperse the unwanted signals (fat signals) so that images can be reconstructed from the signals produced by the wanted components only (e.g. water signals), there is an inevitable distortion of signals due to the main field inhomogeneity: a certain amount of 'abnormal' off-resonance water components is generated by the main field inhomogeneity, which tend to have phase differences compared to the 'normal' on-resonance water components. By using the double off-resonance RF pulses with additional gradients as illustrated in Fig. 1, instead of a single off-resonance RF, the phase offsets induced in the on-resonance spins by the first α_x RF pulse can be compensated by the second α_{x+180° RF pulse.

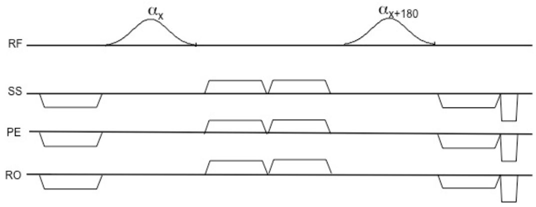

Fig. 1 Sequence diagram of the proposed double off-resonance RF pulses

Results

To verify the performance of the proposed fat suppression technique, images were acquired with the turbo-spin-echo (TSE) sequence at a 3T Verio system (Siemens, Erlangen). For shoulder, coronal PD images w ere acquired from a female patient with the following parameters: TR = 3000 ms, TE = 34 mm, matrix size = 320 × 320, FOV = 160 × 160 mm ^{2}, number of slices = 20, slice thickness = 3 mm, number of averages = 1. For knee, sagittal T1, T2, and PD images were acquired from a he althy male volunteer with the following parameters: matrix size = 256 × 256, FOV = 220 × 220 mm^2, number of slices = 20, slice thickness = 4 mm, number of averages = 1. TR/TEs were 700/19 ms for T1, 4500/74 ms for T2, and 3500/37 ms for PD. The acquired images with different fat suppression techniques combined with TSE sequences are presented in Figs. 2 and 3. As the figures demonstrate, the proposed method produces images that have efficiently suppressed fat signals.

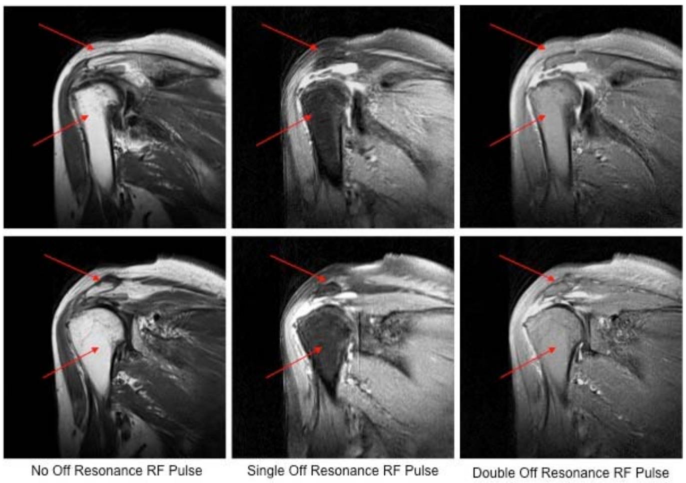

Fig. 2 Shoulder images acquired with different preparation RF pulses.

Discussion

As demonstrated by the experiments, the proposed method can efficiently suppress fat signals without generating additional artifacts that are caused by phase differences (e.g. ringing), which are otherwise observed in the images acquired with the conventional fat saturation technique. Although the fat signal is more strongly suppressed by the single off-resonance RF pulse, the proposed method is more beneficial for diagnostic purposes due to uniformity in the image intensity and preservation of structural details (e.g. ligaments) from image artifacts caused by field inhomogeneities.

Conclusion

To alter image contrast in routine MR imaging sequences, a preparatory pulse of low amplitude and short duration is applied at a specific frequency offset down field from water resonance before a conventional imaging sequence[2]. While standard pulse sequences with an off-resonance RF are commercially available, some of these sequences are not optimal in 3T MRI especially for periphery imaging. In this study, an alternative method is presented to perform fat suppression in the presence of substantial amount of field inhomogeneity.

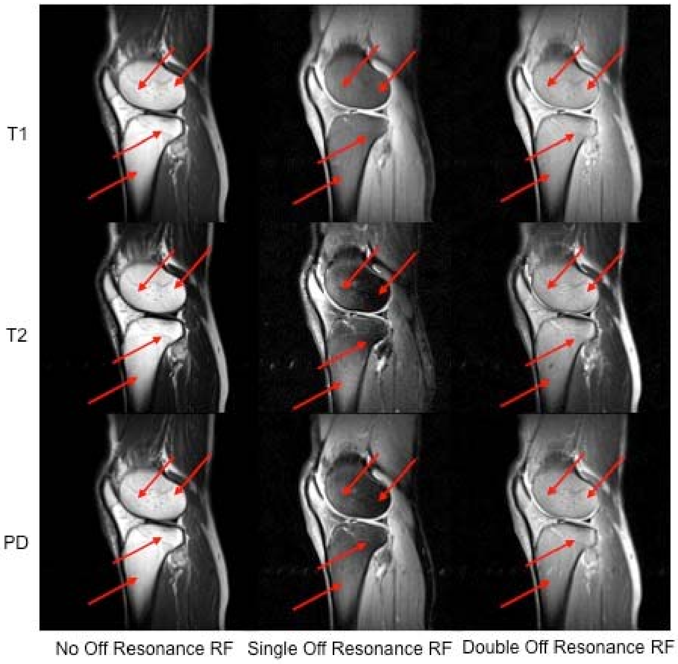

Fig. 3 Knee images acquired with different preparation RF pulses

References

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