T2-TIDE-bSSFP Imaging with Simple And Robust Fat Suppression

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Introduction

The balanced steady-state free precession (bSSFP) imaging with preparatory pulses using the transition into driven equilibrium (TIDE) technique [1] has been shown to provide smooth signal transition for a wide range of off-resonance conditions, leading to substantially reduced Nyquist ghosts. A recent study further shows that T2 contrast could be added to the TIDE-bSSFP images by insertion of a series of 180° pulses (T2-TIDE-bSSFP) [2]. Since bSSFP imaging is widely used in cardiac and abdominal studies where the presence of fat signals often interferes with clinical diagnosis, we propose in this study a fat-suppressed T2-TIDE-bSSFP technique which uses a unique property inherent in TIDE-bSSFP to achieve robust fat suppression.

Materials and Methods

As a simple test without loss of generality, we chose a four-step TIDE preparation [1] targeted at the final flip angle of 90°, which was preceded by a series of eight 180° pulses for T2-weighting [2]. The RF pulsing scheme was therefore $[90° \; 180°\times8 \; 150° \; 120° \; 90°]_{prep}[90°\ldots]_{acq}$ with phase alternation every other pulses. A TR of 6.46 msec was used for all pulse intervals, except the first one which was TR/2 [1]. Figure 1 shows the signal evolution for the first 256 RF pulses at different SSFP angles (i.e., different off-resonance conditions), calculated from computer simulation results using the Bloch equation. It is seen that from the 15th to the 30th RF pulse, the signals are close to zero for a wide range of SSFP angles (spanning about 180° to 540°, dotted boxes in Fig.1). This means that if half Fourier imaging is applied to TIDE-bSSFP, a large portion of the data near central k-space would be nulled for these off-resonance spins. By placing the fat frequency within the null bands, effective fat suppression could be achieved. One notices two important characteristics of this technique: First, since the signal null bands are wide, fat suppression can be done robustly without stringent shimming requirements; second, no additional modification on the TIDE-bSSFP sequence needs to be performed except the choice of HASTE-type phase encoding.

Two-dimensional coronal abdominal images were acquired on a 1.5T system (Siemens Vision+, Erlangen, Germany) using T2-TIDE preparation with bSSFP readout (TR/TE = 6.46/3.23 msec flip angle of 90°). At this TR, the chemical shift of fat protons corresponds to –520° SSFP angle. The matrix size was 256×256 (half Fourier) using HASTE-type phase-encoding order. For comparison purpose, the same sequence was used with full k-space coverage using linear phase-encoding order, which is anticipated to yield images showing no fat suppression because the contrast is dominated at the 128th TR.

Results

Figures 2a and 2b showed the abdominal images acquired using T2-TIDE-bSSFP with and without half Fourier option, respectively. Fig.2a exhibits nearly complete fat suppression, even if the fat frequency was intentionally placed at the edge of null bands (cf. Fig.1). Some residual fat signals were seen (arrows), demonstrating a deviation of resonance frequency from the null bands. In contrast, Fig.2b without choosing half Fourier option showed strong fat signals. The experimental results were in good agreement with predictions from the computer simulations.

Discussion and Conclusion

In this study, we show that by a simple manipulation of HASTE-type phase encoding, T2-TIDE-bSSFP imaging can be performed with robust fat suppression. In contrast to other fat suppression schemes for bSSFP imaging, the proposed approach does not need sophisticated pulse sequence modifications [3-4] except the selection of half-Fourier option; it does not need two scans to separate water and fat signals [5]; and it is not prone to errors in the presence of partial volume mixture of fat and water [6]. The T2-TIDE technique preserves the rapid scan time of bSSFP, because only a small of number of preparatory pulses are employed. Consequently, fat-suppressed T2-TIDE-bSSFP imaging has the potential for routine clinical applications in abdominal and cardiac imaging.

References

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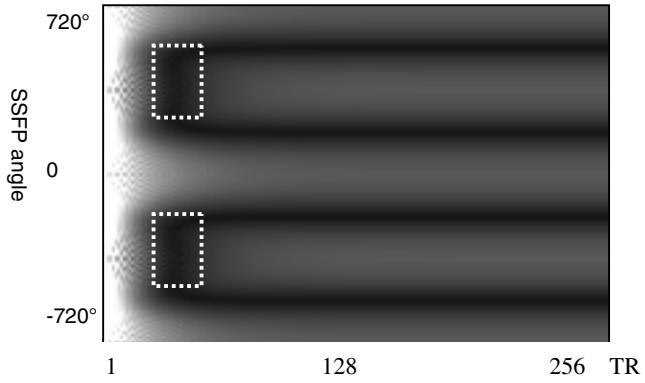

Fig.1. Signal evolution for 256 RF pulses at different SSFP angles. Signals are close to zero from the 15th to the 30th RF pulse for a wide range of SSFP angles (dotted boxes), suitable for robust fat suppression.

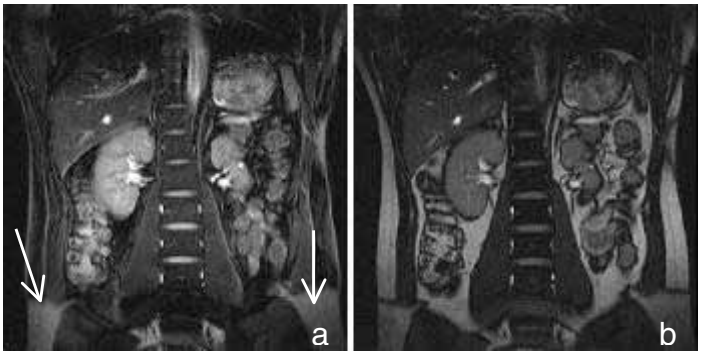

Fig.2. T2-TIDE-bSSFP images acquired with (a) and without (b) half Fourier option. Fat suppression is clearly evident in (a). Some residual fat signals are seen (arrows), corresponding to deviation of the resonance frequency from the null bands in Fig.1.