Analysis of Composite Pulse Schemes for Abdominal Fat Suppression

A. J. Wheaton[1], M. Miyazaki[1,2], and S. Kitane[3]

[1]Toshiba Medical Research Institute, Mayfield, OH, United States, [2]Toshiba America Medical Systems, Tustin, CA, United States, [3]Toshiba Medical Engineering Co., Tochigi, Japan

PURPOSE

Spectral-selective SPIR is commonly employed for fat suppression in fast abdominal imaging. In short TR acquisitions, for SAR and timing considerations, the SPIR pulse is applied only once per segment group of PE lines. Also, the SPIR pulse is often under-tipped with a flip angle ranging from 90°–120°. At low tip angles near 90°, the performance of SPIR becomes increasingly sensitive to B1 inhomogeneity.

Composite pulse schemes are known to improve the B1 and T1 robustness of spectral suppression performance. One such technique is WET [1] where a ~90° spectral-selective pulse is repeated N times for better ΔB1 and ΔT1 robustness. Our proposal is to use a 2- or 3- composite pulse spectral-selection scheme for improved abdominal fat suppression performance. We call the 2-pulse scheme Double Fat Suppression [DFS] and the 3-pulse scheme Triple Fat Suppression [TFS]. The application of extra pulses comes at a cost of longer scan time and greater SAR. The purpose of this study is to estimate which technique [SPIR, DFS, TFS] is expected to produce the best performance and efficiency in the presence of ΔB1 and ΔT1.

MODELING

Numerical Bloch-equation solutions for SPIR, DFS, and TFS were used to model the relative fat suppression performance of each technique. We used sequence parameters: TR/TE=9.0/4.8 ms, FA= 20°, matrix=160x256, 30 slices, parallel imaging factor=2.0, SPIR FA = 95°, and SPIR TI = 20 ms. The numerical solutions were repeated with a range of ΔB1=±20% and ΔT1=±10% for 100 steps each. The model used a realistic multi-component model of human fat where the signal contribution from each fat component [i.e. CH_3] was calculated individually using its T1 and chemical shift at 1.5T [2]. ΔT1 was incorporated by scaling the T1 of each fat component. ΔB1 was incorporated by scaling the selection profile of each pulse. All pulses were modeled using a 5.7ms 5-lobe sinc pulse. DFS and TFS used a 95° SPIR pulse [20 ms delay] followed by [n=2 or 3] 90° pulses [each with 16 ms delay for spoiling].

MR EXPERIMENTS

To measure the effect of segmentation, baseline SPIR data were acquired using a Toshiba Vantage 1.5-T system with the 3D FFE QUICK sequence (comparable to VIBE or LAVA) and the same sequence parameters as the model. A safflower oil phantom with T1 = 230 ms was used to simulate basic fat. The effect of segmentation was evaluated by varying the number of PE steps between the application of fat sat pulse clusters. K-space was segmented using interleaved ordering (sequential in the slice encode direction and centric in the PE direction). The number of segments [Nseg] used was 1, 2, 4, and 8. To validate the model data relative to SPIR, DFS data were acquired in the same way using a DFS-modified version of 3D FFE QUICK.

FAT SUPPRESSION TECHNIQUE COMPARISON

For each step of ΔB1, ΔT1, and Nseg, the performance of each technique was calculated by scaling the model data at each [ΔB1,ΔT1] with the baseline experimental data for each Nseg. Fat sat performance was normalized based on the experimental SPIR data at Nseg = 1 [assuming ΔB1=ΔT1=0%]. The total scan time for each technique was calculated at each Nseg using the pulse durations and TR described above. SAR was calculated using a pulse energy model. Time-efficiency [= performance / scan time] and SAR-efficiency [= performance / total SAR] were calculated using the model data. Performance, time-efficiency, and SAR-efficiency data were normalized relative to values of the experimental SPIR data at Nseg = 1.

RESULTS AND DISCUSSION

The DFS/SPIR performance ratio of the model data at ΔB1=ΔT1=0% [1.114] closely matched the performance ratio the experimental data [1.129] validating that our model was reasonable. The performance of DFS and TFS relative to SPIR across [ΔB1, ΔT1] is displayed in Figures 1 and 2. Adding the 3rd pulse in TFS gains additional B1-robustness. Over the whole range of [ΔB1,ΔT1], DFS was on average 11.0% better and TFS 13.6% better than SPIR. There was relatively little variation along the ΔT1 dimension which is expected in short TR conditions when the flip angles in a multi-pulse scheme are fixed [1].

The fat sat performance of each technique as a function of Nseg for the extrema of ΔB1 = -20%, 0%, and +20% is plotted in Figure 3. Performance of TFS > DFS > SPIR across all Nseg for all ΔB1. However, TFS is less time-efficient than DFS and SPIR [Figure 4]. At ΔB1=0%, in both performance and time-efficiency DFS and TFS are nearly equal and better than SPIR. For larger ΔB1 [±20%] TFS is better than both DFS and SPIR. TFS is the most SAR-intensive technique and therefore has decreased SAR-efficiency [Figure 5]. At Nseg >1, the SAR-efficiency of all techniques are comparable, with SPIR being the most SAR-efficient in many cases.

This type of comparative analysis will guide further investigations to consider the choice of these techniques based on expected levels of B1 inhomogeneity and T1 variation plus acquisition time and SAR constraints.

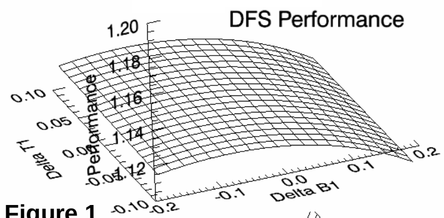

Figure 1

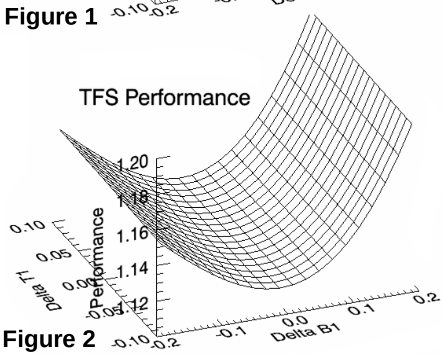

Figure 2

REFERENCES: [1] Ogg, Kingsley, Taylor. J Magn Reson B 1994; 104; 1-10.

[2] Kuroda, Oshio, Mulkern, Jolesz. Magn Reson Med 1997; 40: 505-510.

Figure 3: Performance

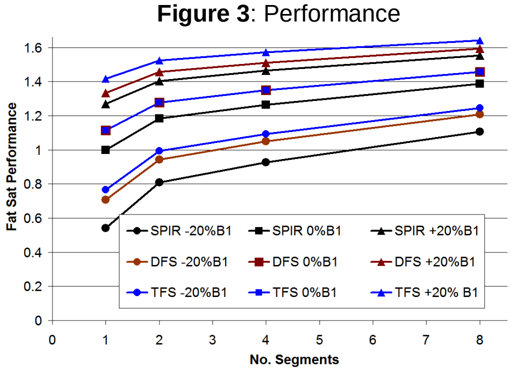

Figure 4: Time-efficiency

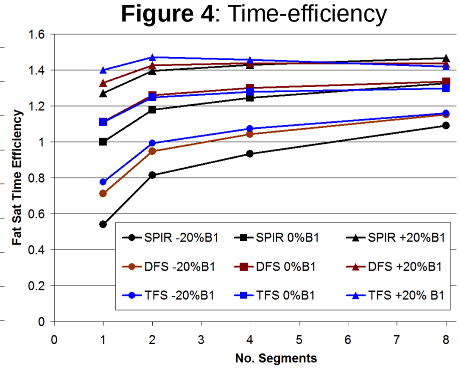

Figure 5: SAR-efficiency