Fat-signal Suppression in Single-slab 3D TSE (SPACE) using Water-Selective Refocusing

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Introduction: Optimized versions of single-slab, three-dimensional fast/turbo spin echo (FSE/TSE) imaging (e.g., SPACE [Siemens] or 3D FSE CUBE [GE]) have recently gained popularity for a variety of clinical applications. An extended first echo spacing [1,2] has been used in single-slab 3D TSE to accommodate the relatively long excitation RF pulse required to achieve slab-selection [3]. Since, with an extended first-echo-spacing pulse-sequence structure, relatively long pulse durations can be used for the excitation and/or first refocusing RF pulses without sacrificing short echo spacings for the remaining echoes, this structure offers the opportunity to introduce additional pulse-sequence features through the properties of these two RF pulses without compromising the efficiency of the technique. In this work, we investigate the possibility of using a water-selective refocusing RF pulse to achieve fat-signal suppression for slab-selective single-slab 3D-TSE imaging.

Methods: **Fig. 1** illustrates the RF-pulse and slice-select gradient configuration shown previously for a slab-selective implementation of single-slab 3D TSE [3]. Our method replaces the non-selective, 180° refocusing RF pulse with a spectrally-selective RF pulse, as illustrated in the inset, which refocuses only the water (or fat) magnetization. Spoiling gradients (not shown) surrounding this spectrally-selective RF pulse dephase the spectral component that is not refocused, so that it does not contribute to subsequent echoes.

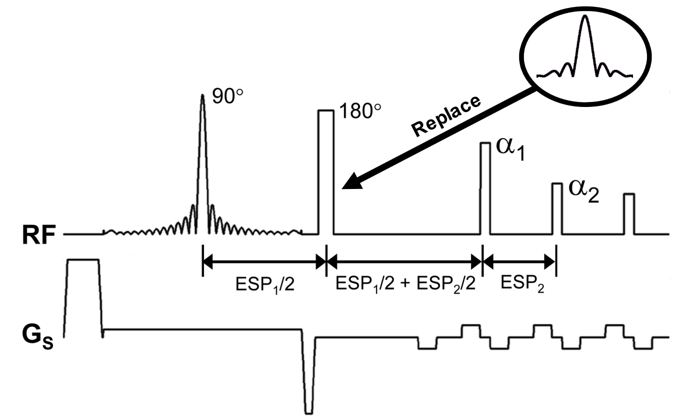

Fig. 1. Timing diagram of the section-select gradient (G_S) and RF pulses for the initial portion of a spatially-selective, single-slab 3D-TSE pulse sequence [3]. As illustrated by the inset, the non-selective 180° RF pulse is replaced by a spectrally-selective 180° RF pulse. Magnitude RF waveforms are shown.

A commercial version of single-slab 3D TSE (SPACE) was modified to include a spectrally-selective first refocusing RF pulse designed to refocus only the water component at 3T. As is well known, the pulse duration and waveform can be manipulated to obtain desired RF-pulse pass-band and stop-band characteristics. For this preliminary implementation, we chose: pulse duration, 15.36 ms; bandwidth, 500 Hz (full width at half maximum); and transition bandwidth, 90 Hz. The basic operation of the technique was tested at 3T (Trio, Siemens) using a spherical phantom by measuring the signal intensity versus off-resonance frequency. The fat suppression performance of the sequence was then tested by acquiring T2-weighted 3D-TSE images (TR 3000 ms, variable-flip-angle echo train [133 echoes] with effective TE 222 ms, contrast-equivalent TE 93 ms) of the lumbar spine of a healthy volunteer. T1-weighted 2D-TSE images (without fat suppression, TR 650 ms, TE 9.4 ms) were also acquired for reference. Informed consent was obtained prior to imaging.

Results: The phantom images versus off-resonance frequency shown in **Fig. 2** illustrate that the spectrally-selective RF pulse transitions from refocusing to suppression at a frequency of between 200 and 300 Hz, consistent with the theoretical design parameters for the pulse. The normalized signal intensities were 1.00, 0.98, 0.64, 0.06 and 0.0 (noise) for off-resonance frequencies of 0, -100, -200, -300 and -400 Hz, respectively. The T2-weighted sagittal lumbar-spine image of **Fig. 3** illustrates excellent suppression of fat-containing tissues.

Conclusions: We have demonstrated that a spectrally-selective RF pulse can be used as the first refocusing RF pulse in slab-selective, single-slab 3D-TSE imaging to achieve fat suppression. This approach slightly extends the echo-train duration, but does not affect the echo spacing for the remainder of the echo train. Compared to conventional, spectrally-selective pre-pulses for fat suppression, the method illustrated here is insensitive to the degree that the fat magnetization is relaxed. The method is also insensitive to shifts of the fat frequency away from the water frequency due to field inhomogeneity. Future studies will focus on optimizing the characteristics of the spectrally-selective refocusing RF pulse and on evaluating the efficacy of this method compared to established methods for fat-signal suppression.

References: **1.** Kanazawa H et al. Proc SMR 2 (1994); 474. **2.** Mitsouras D et al. Med Phys 2006; 33:173. **3.** Mugler JP et al. Proc ISMRM 12 (2004); 695.

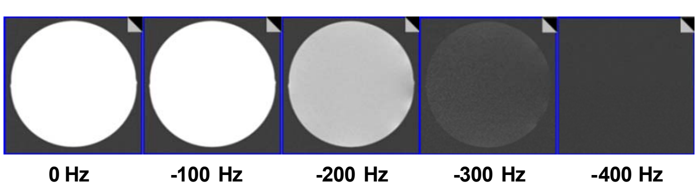

Fig. 2. Center slice from 3D-TSE acquisitions of a spherical phantom as a function of off-resonance frequency from 0 to -400 Hz, demonstrating the frequency-selective characteristics of the first refocusing RF pulse. Window/center settings are identical for all images.

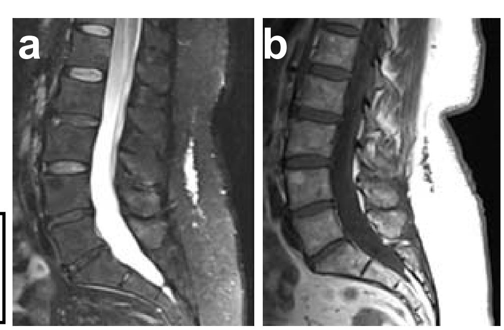

Fig. 3. (**a**) Sagittal slice from a T2W single-slab 3D-TSE acquisition using a water-selective refocusing RF pulse to suppress fat. (**b**) Sagittal T1W 2D-TSE image for comparison.