Fast dynamic fat-water separation using shorter spatial-spectral excitation and novel temporal acquisition

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Introduction: Many dynamic applications can benefit from reliable fat-water separation. Examples include temperature monitoring for ablation therapy (where fat signals can corrupt temperature measurements) and cardiac imaging (where fat infiltrations can indicate disease). Spectral-spatial pulses (SPSP) [1] are a common way of exciting only the water or fat content of an imaged slice or volume. However, the duration of SPSP pulses may be as much as 10 ms or more, making them impractical for short-TR sequences. Furthermore, their fat-water separation properties may be degraded by B_0 inhomogeneities. A different fat-water separation technique, related to the UNFOLD temporal strategy [2], is combined here with a SPSP pulse for added performance. The duration of our SPSP pulse was reduced to only about 2 ms, making it readily compatible with most short TR/TE sequences. Fat signals imperfectly suppressed by the short pulse were further suppressed by the temporal strategy. The resulting hybrid approach should outperform SPSP pulses in the presence of field inhomogeneities and/or in cases where pulse duration must be significantly reduced, and outperform the temporal scheme from when very dynamic motion is present.

Methods and Results: The SPSP pulse was designed using a 2DRF pulse library [www.ncigt.org]. TE was made to vary by ΔTE with a periodicity of 4 frames [0, 0.8*ms*, 0, 0.4*ms*] while TR was kept constant. Due to the offset frequency of fat (Δf), the ΔTE variations induced periodical phase variations of $2\pi\Delta f\Delta TE(t)$ in the fat signal. These phase variations acted as a 'fingerprint' in identifying fat signal through temporal processing. Following an FFT along the time axis, fat signals were identified using an approach closely related to a matching pursuit algorithm [3]. The proposed strategy for fat-water separation was implemented on a SSFP sequence, and tested at 3T using a moving phantom and *in vivo* free-breathing abdominal imaging. For both phantom and abdominal imaging, a 3*680μs SPSP pulse was used. The phantom moved back-and-forth along the *S/I* direction over a range of 2 cm, with a periodicity of about 5s. The phantom's motion is evidenced by the changes in radius for the fat compartment, which consisted of olive oil in a tapered bottle (see Fig. 1). Figure 1 shows the phase image for time frames 1-16. The phase variations through all frames are plotted in Fig. 2 for the two pixels highlighted in Fig. 1. Figure 3 compares images from a regular RF pulse (Fig. 3a), the SPSP pulse without the temporal scheme (Fig. 3b), the fat signal imperfectly suppressed by the SPSP pulse but identified as fat by the temporal scheme (Fig. 3c), and the final fat-suppressed result where both the SPSP pulse and the temporal scheme contributed to the suppression (Fig. 3d). For all time frames, the water/fat ratio was more than an order of magnitude better using the hybrid approach compared to the SPSP pulse alone (Fig. 4). Figure 5 shows *in-vivo* free-breathing abdominal results, using an 8-channel torso array, where the proposed approach was used for fat suppression. The short SPSP fails partly in subcuteneous fat suppression because of the susceptibilities near the boundary. By combining the temporal processing at the reconstruction stage, the residual fat is successfully removed.

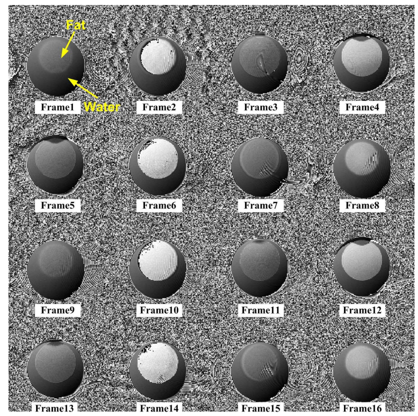

Fig.1. Phase images from frame 1-16.

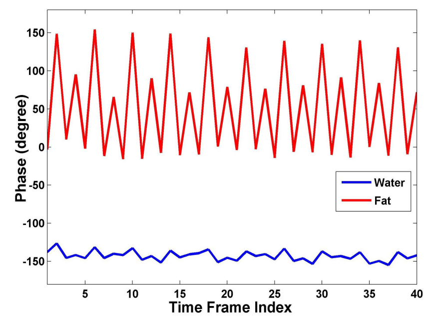

Fig.2. Phase variations through all time frames

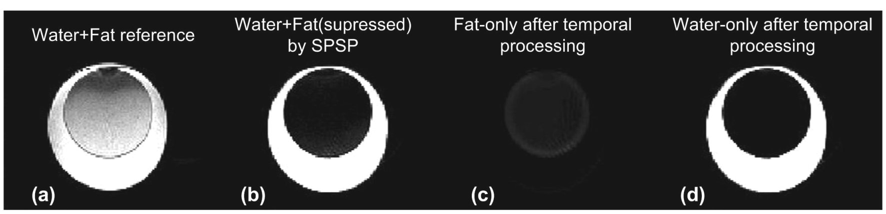

Fig.3. (a) Reference image by normal excitation; (b) a short 3*680μs SPSP excitation suppresses most fat signal; (c) Fat-only image by applying temporal processing to (b); (d) Water-only image by subtracting fat component (c) from (b). Parameters: Axial view, FOV=16cm, matrix=128X128, TR=3.8ms for (a) and TR=5ms for (b-d)

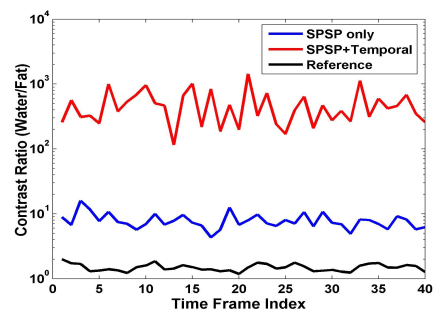

Fig.4. Water/fat contrast through all time frames

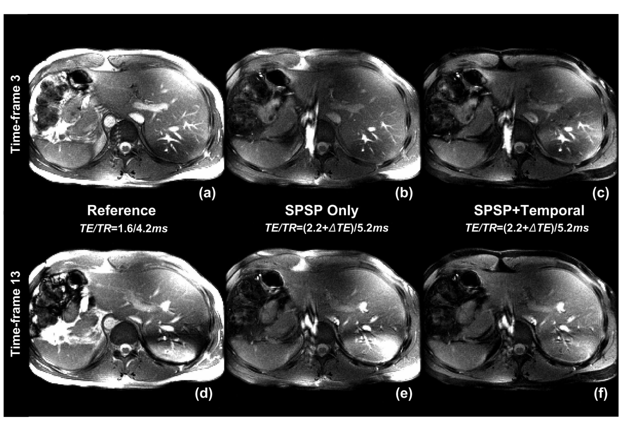

Fig.5. Fat suppression in free-breathing abdominal imaging at 3T. 3*680us 2DRF, FOV=32cm, matrix=192x192, thickness=8mm, bandwidth=125KHz.

Discussion: SPSP is sensitive to field inhomogeneity (see Fig. 5b and Fig. 5e) but insensitive to motion. On the contrary, temporal processing is more sensitive to motion than inhomogeneity, as sudden motion may partly confuse the temporal encoding scheme (e.g., see Fig. 3c near the boundary). By combining these two strategies, their respective strengths can be combined, and their individual weaknesses overcome. This novel fat-water separation technique is promising to benefit fast dynamic imaging applications. **Acknowledgement:** NIH grant 1U41RR019703-01A2

References: [1] CH Meyer *et al*, MRM 15:287-304(1990); [2] RS Ababneh *et al*, 15th ISMRM 3870 (2007); [3] B Madore *et al*, MRM 55:352-362(2006);