Spatially variable fat-water separation using short 2DRF pulses for fast imaging

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Introduction: 2DRF pulses have been introduced for fat-water separation by taking advantage of large spatial shifts of fat along the phase-encoding (PE) direction [1, 2]. However, these 2DRF pulses and traditional spatial-spectral (SPSP) pulses only create uniform fat/water contrast within the FOV. Their usefulness may be limited by the relatively long duration, especially for fast-imaging sequences with short TR such as SSFP imaging. In this study, we demonstrated that spatially variable fat-water separation could be achieved in a fractional FOV by a shorter 2DRF than that for full-FOV separation. Furthermore, reduced FOV (rFOV) imaging and partial-Fourier reconstruction can also be combined with this technology, to accelerate imaging speed further.

Methods and Results: Our 2DRF design strategy to achieve spatially variable fat-water separation is described in Fig. 1, using a small flip angle approximation [3] and the VERSE algorithm [4]. The distance between two neighboring excitation profiles along the PE direction is called the 'field of excitation' (FOE), which is equal to the sum of the passband, stopband, and two transition widths ($W_p+W_s+2W_t$). The FOE is determined by the blip gradient area ($FOE=1/a_{blip}$). The spatial shift for fat (ΔS) is given by $\Delta S=\Delta f*Tsub*FOE$. Assumed water is on resonance and the imaging object is in the range FOV_1, the left half FOV would be a fat-water combined image while the right half would show water-only. Different spatially varying fat-water contrasts could be achieved in $FOV_{2,3,4}$ by adjusting 2DRF sub-pulse phases to create different passband and stopband distributions for fat and water. Responses to a 2DRF pulse with different parameters are simulated in Fig. 2. Fig.2a and 2c show full FOV separation with different pulse durations and *FOE/FOV* ratios. By increasing sub-pulses in Fig.2a to increase W_s/W_p, separation could be achieved with rFOV in Fig.2b. By reducing pulse duration in Fig.2c, fat experiences smaller shift along PE. Thus, spatially varying fat-water contrast could be achieved in the FOV with an appropriate *FOE/FOV* ratio. The reduction factors of 1.3, 2.0 and 3.7 in pulse length have been achieved compared to those used in Fig. 2c, 2a and 2b respectively. Abdominal imaging were performed at 3T (TE/TR=8/14ms, flip=45^o, matrix =256*256, thickness=8mm) to verify the proposed method using a fast gradient-echo sequence. Spatially variable fat-water contrasts, corresponding to $FOV_{1,2,3,4}$ in Fig. 1, were achieved in Fig. 4 by a 23% shorter 2DRF than that used in Fig. 3. In Fig.4b and Fig.4c, since half FOV shows signal null for both water and fat, a fractional phase FOV could be applied to reduce the number of phase encodes. Partial Fourier reconstruction could then be employed for further scan time reduction.

Discussion: Flexible fat and water distributions could be created by manipulating the blip gradient area, the number of sub-pulses, the duration and the phase of the 2DRF sub-pulses. In Fig. 4, we showed that good fat-water separation can be obtained with a pulse as short as 2.8 ms at 3T, especially if the desired contrast (e.g., water-only) is required only over a part of the FOV. The approach could be extended to separate water and other off-resonance spins such as silicon. The short 2DRF is compatible with other fast sequences, such as SSFP, FSE and EPI, and has advantages for applications in image-guided therapy where the ROI for separation could be pre-determined, such as MR-guided focused-ultrasound temperature mapping.

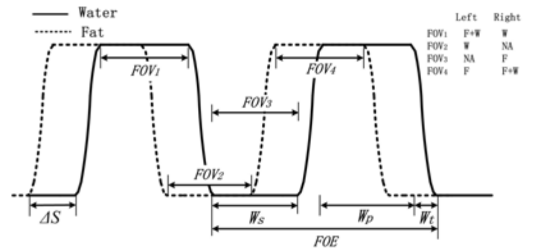

Fig.1. Spatially variable fat-water separation with a 2DRF pulse

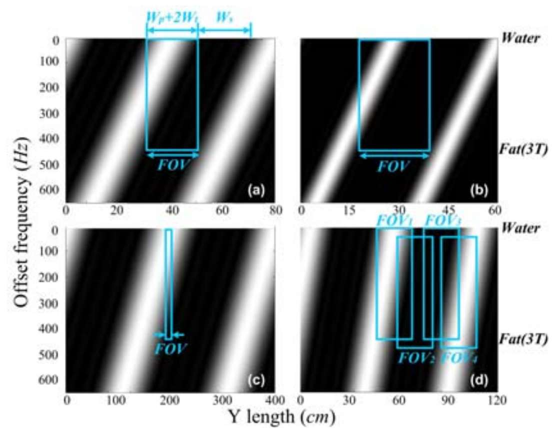

Fig.2. (a) full FOV fat-water separation at 3T with a 5*1136μs pulse; (b) rFOV separation (R_{FOV}=2) with a 9*1136μs pulse; (c) full FOV separation with a 5*720μs pulse; (d) spatially variable separations with a 5*560μs pulse.

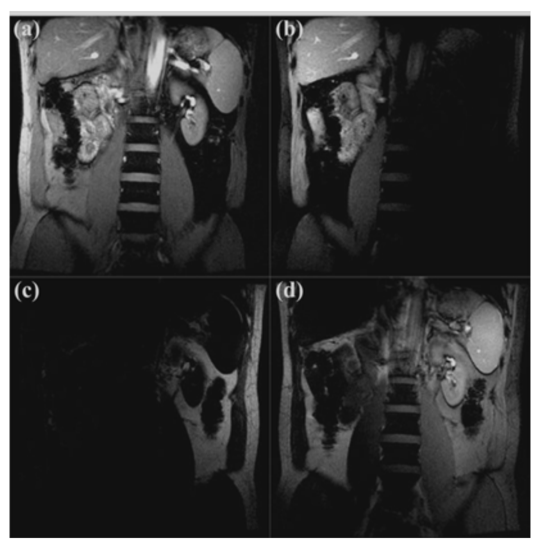

Fig.4. Spatially variable fat-water separation at 3T with a 5*560μs pulse (a) left: fat+water, right: water-only (b) left: water-only, right: signal null; (c) left: signal null, right: fat-only (d) left: fat-only, right: fat+water.

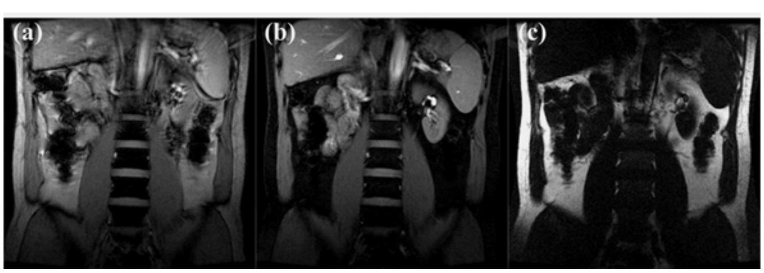

Fig.3. Full FOV fat-water separation at 3T by a 5*720 μs 2DRF pulse (a) Reference image by the original SINC pulse; (b) Water-only image; (b) Fat-only image;

References: [1] J Yuan et al, 16th ISMRM 1388(2008); [2] K Sung et al, 15th ISMRM 3010 (2006); [3] J. Pauly et al, JMR 81:43-56 (1989); [4] BA Hargreaves et al, MRM 52:590-597 (2004).

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