Fat Suppression in Single Acquisition Steady-State Free Precession Using Multiple Echo Radial Trajectories

A. Lu[1], H. A. Rowley[2], T. M. Grist[1,2], W. F. Block[1,3]

[1]Department of Biomedical Engineering, University of Wisconsin-Madison, Madison, WI, United States, [2]Radiology, University of Wisconsin-Madison, Madison, WI, United States, [3]Department of Medical Physics, University of Wisconsin-Madison, Madison, WI, United States

INTRODUCTION

Fat/water separation in fully refocused SSFP (FIESTA, true-FISP, balanced FFE) using phase detection, recently introduced by Hargreaves *et al*. [1], removes the need for dual acquisition in linear combination SSFP (LC-SSFP) [2]. An echo time at the midpoint of the TR exploits the π phase shift between the fat and water transverse steady states. Meanwhile, the dual half echo VIPR sequence [3] was originally developed to increase the scan efficiency of radial sequences for LC-SSFP. We present a method to linearly combine the echoes acquired at the beginning and the end of the TR in dual-echo VIPR to suppress either fat or water in a single acquisition. Angiography and musculoskeletal applications with a 50% scan time reductions from LC-SSFP VIPR are demonstrated.

MATERIALS AND METHODS

The dual-echo implementation of VIPR sequence acquires two radial lines in k-space each TR in a form similar to a half "bowtie" (Fig. 1a). One echo is formed immediately after RF excitation while the other is formed near the end of the TR. As shown in Fig. 1b, water and fat signals exhibits different phases in these two echoes if the center frequency is placed half way between their resonance frequencies. Although the technique can work for various echo times, the fat and water vectors simply counter-rotate 90 degrees when the difference in echo time is 2.2 ms. By linearly combining these two echoes, either fat (echo1+i*echo2) or water (echo1-i*echo2) suppression can be created (Fig. 1d). The unwanted species is not suppressed as well as in LC-SSFP (Fig 1c) but the desired passband is much wider as shown in Fig. 1d. However, since the phases (Fig. 1e) of the suppressed band can be clearly discriminated, a threshold technique can be applied to display only those pixels whose phases fall outside the suppressed band.

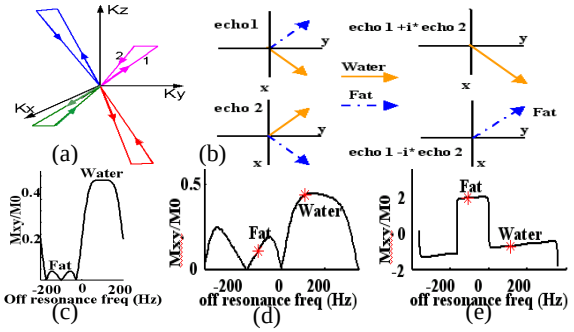

Fig.1 (a) Dual-echo VIPR k-space trajectories (4 TRs shown) b) Fat and water spins counter rotate over TR thus combination of the two echoes suppresses fat (dashed) or water (solid). c) LC-SSFP spectral response shows a passband width of 1/(2TR). d) Spectral and (e) phase response of the combined signal for fat suppression. (Asterisks denote fat/water freqs relative to the center freq)

RESULTS AND DISCUSSION

All imaging volumes were acquired on a 1.5 T Signa™ scanner (GE Medical Systems, Milwaukee, WI) over a 24 cm spherical FOV with 0.94 mm isotropic resolution in 75 seconds (TR/TE1/TE2 = 2.6/0.3/1.9 ms). The head image (Fig. 2b) shows excellent fat suppression and no signal dropout, which is seen in the standard LC-SSFP water image (Fig. 2a), demonstrating the new method is more robust to B_0 inhomogeneity. The capability of this technique for non-contrast enhanced MR angiography is shown in Fig. 3, where a sagittal (Fig. 3a) and a coronal (Fig. 3b) MIP of the head depict the carotid and vertebral arteries in great detail. The knee reformats (Fig 4) demonstrate good fat (4a) and water (4b) separation by combining echoes. After applying the phase masking technique, as shown in Fig. 4c, a water-only image is generated with excellent depiction of the cartilage (arrows).

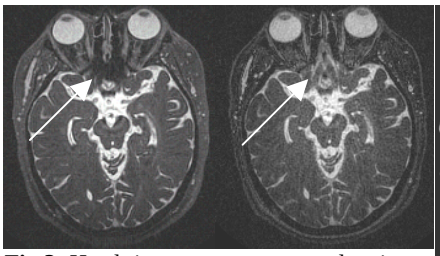

Fig.2 Head images reconstructed using LC SSFP (a) and the new method (b) show good fat suppression. The new method uses only half of the data as LC SSFP. Signal dropout in (a) is not seen in (b) (arrows).

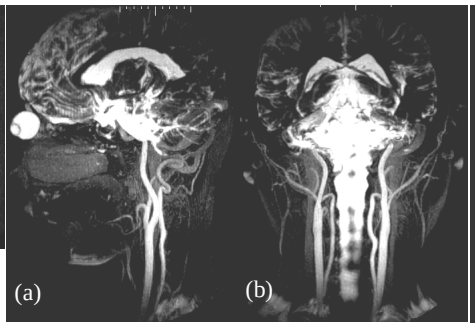

Fig. 3 (a) Sagittal, b) Coronal water volume MIPs show excellent detail of the carotid and vertebral arteries w/o contrast injection in 75 s.

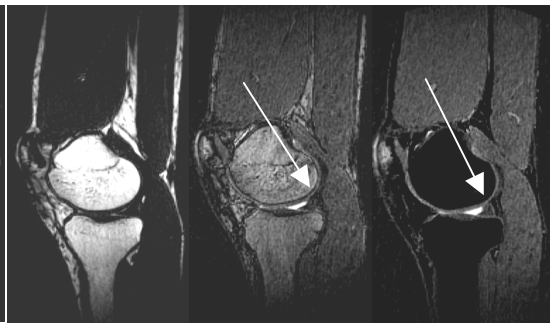

Fig. 4 Knee images showing fat/water separation. a) Fat and b) Water images. c) Further fat suppression achieved by phase masking improves cartilage contrast.

CONCLUSIONS

The new fat/water suppression technique exploits the off-resonance phase accrual at different echo times within each excitation to achieve excellent fat and water separation in a single acquisition. It is also very robust to field inhomogeneity. Our volunteer studies demonstrate that this technique provides a promising approach for MR angiography, head/neck and musculoskeletal imaging.

REFERENCES

1. B. Hargreaves , et al., MRM 50 210 (2003) 2. S. Vasanawala, et al., MRM, **43** 82 (2000) 3. A. Lu, et al., Proc. 11th ISMRM, 320 (2003)