Fat-Suppressed Cine SSFP Coronary Angiography

P. Hu[1], C. H. Meyer[2]

[1]Biomedical Engineering, University of Virginia, Charlottesville, United States, [2]Biomedical Engineering, University of Virginia, Charlottesville, VA, United States

Introduction: The goal of this study was to develop a fat-suppressed cine SSFP sequence for gated, time-resolved coronary angiography. Refocused SSFP (SSFP, TrueFISP, FIESTA, Balanced FFE) sequences are widely used in cardiac imaging [1], because of their high SNR and excellent contrast between blood and myocardium. Cine SSFP sequences are not typically used for coronary angiography, because these sequences do not include fat suppression and the major coronary vessels are surrounded by fat. Investigators have studied gated SSFP coronary sequences that interrupt the steady-state to apply saturation pulses [2-5]. The FEMR technique has been used to suppress fat in peripheral angiography [6]. We have combined a cine SSFP sequence with FEMR to acquire 2D coronary artery movies with steady-state cardiac gating.

Methods: Figure 1 shows the cine SSFP FEMR sequence. With steady state maintained throughout the heart cycle, the RF phase alternates between 0 and 90 degrees and the system frequency is midway between the resonance frequency of water and fat. Additionally, each phase encoding line is duplicated for the readouts after the 0 and 90 RF phases. The data acquisition was active only after the 90 RF phase, so that only fat-suppressed images were generated. Figure 2 shows the transverse magnetization profile with respect to off-resonance frequency.

Coronary images of normal volunteers were acquired on a 1.5T Siemens Sonata scanner with a 40mT/m maximum gradient strength and 200 mT/m/s maximum slew rate. The FOV was 20 cm, the in-plane resolution was 1.56 mm, the slice thickness was 7 mm, and the flip angle was 30 degrees. The TR was 2.8 ms and 4 phase encodes were acquired per heartbeat. The resulting temporal resolution was 22.4 ms, with images reconstructed every 11.2 ms using a sliding window.

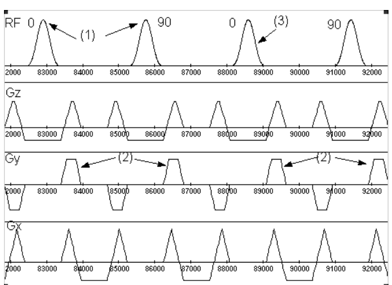

Figure 1: Sequence diagram of cine SSFP sequence combined with FEMR fat suppression. 1) RF phase alternates between 0 and 90 degrees. 2) Each phase encode is repeated for 0 and 90 RF phases. 3) System frequency is midway between the resonance frequencies of fat and water. The data acquisition window was active only after the 90 RF phases, generating a fat-suppressed image.

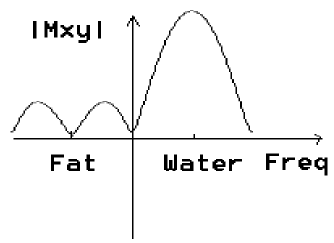

Figure 2: Steady state transverse magnetization versus off-resonance frequency for the 90 RF phase readout. The system frequency is half-way between the resonance frequencies of water and fat.

Results: Figure 3 shows a comparison of two images, one acquired using a standard cine SSFP sequence and one with the cine SSFP sequence combined with FEMR. The left coronary artery system is much better visualized in the fat-suppressed image of Fig. 2(b) than in Fig. 2(a). The fat-suppressed SSFP image maintains good contrast between blood and myocardium throughout the heart cycle, which helps with the visualization of smaller branches and allows a thicker slice to be used. The cine presentation allows the operator to view various coronary segments as they come into the image plane and at the cardiac phases that minimize motion blurring.

Discussion: FEMR can achieve fat suppression of approximately 85% [6] and, at the same time, take advantage of the steady state contrast and high temporal resolution of SSFP sequence, which makes it applicable to coronary artery imaging. Although we have to discard every other readout to achieve fat suppression, we can still acquire cine coronary images during a reasonable breathhold. It is straightforward to trade off temporal resolution for higher spatial resolution.

Conclusion: Cine SSFP combined with FEMR provides SSFP contrast, good fat suppression, which makes it a promising technique for coronary artery imaging.

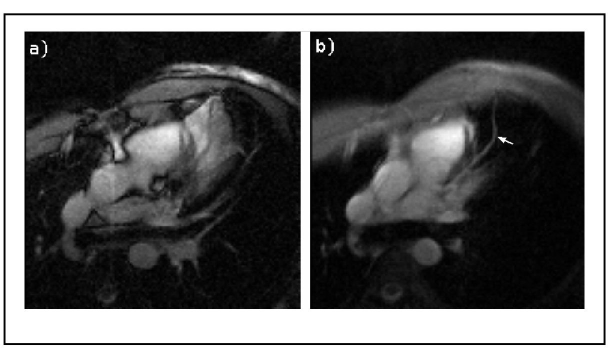

Figure 3: Left coronary artery images acquired with the same imaging parameters using a) cine SSFP sequence without fat suppression and b) cine SSFP combined with FEMR fat suppression. The fat suppression greatly improves the visualization of the LAD and its branches, as do the good blood-myocardium contrast and the cine presentation.

References:

[1] Heid O., et al., Proc Second Annual Meeting Society of Magnetic Resonance, 1994, p.495
[2] Scheffler K, et al. MRM 45:1075-1080(2001)
[3] Hargreaves, B., et al., Proc. ISMRM 10:1589(2002)
[4] Deshpande V, et al., MRM 46:494-502
[5] Santos J., et al., Proc. ISMRM 11:982(2003)
[6]Vasanawala S. et al., MRM 42: 876-883(1999)