Spiral SSFP Coronary Artery Imaging

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MR imaging of coronary arteries requires high SNR combined with myocardium and lipid suppression. Refocused steady-state free-precession (SSFP) imaging offers excellent SNR efficiency and contrast between blood and myocardium. In this work, we combine recently-developed fat-suppression techniques with a breath-held, gated spiral SSFP sequence for coronary artery imaging. The spiral imaging sequence provides isotropic resolution with minimal flow-artifact in an imaging window of just 20 ms on each of 15 heartbeats.

Introduction: Refocused SSFP (True-FISP, FIESTA, balanced-FFE) imaging offers high SNR efficiency for blood with suppressed myocardium signal. A recent method using a cardiac-triggered, fat-suppressed 3DFT SSFP sequence has produced promising coronary MRA results [1]. We have developed a fat-suppressed spiral SSFP sequence that acquires isotropic 2D resolution with improved muscle suppression and reduced transient image artifacts. Initial results show excellent vessel contrast with minimal motion artifact.

Methods: Figure 1 shows the cardiac-gated SSFP imaging sequence. An interleaved spiral readout, with its flow moments appropriately nulled [2], is used for efficient k-space coverage and good flow properties. The steady state is maintained throughout the cardiac cycle to suppress muscle signal. The magnetization is periodically tipped out of steady state to apply spectral saturation pulses for fat suppression [3]. Following this, different schemes are applied to rapidly manipulate the magnetization back to its steady state direction [4,5].

Cardiac Trigger
RF
Gx
Gy
Gz
Figure 1: Following a cardiac trigger (1), a spectrally-selective saturation (2) suppresses signal from fat. A spiral SSFP sequence (3) is used, with additional fat suppression modules. After imaging, the steady-state is maintained (4) until the next cardiac trigger to help suppress muscle signal.

Coronary and short-axis image of normal volunteers were acquired on a 1.5 T GE Signa LX scanner with 40 mT/m gradients and 150 mT/m/s slew rates using a 5-inch surface coil. Images are 8 mm slices with 1.2 mm in-plane resolution over a 20 cm FOV. A flip angle of 60° and TR of 5.2 ms were used to achieve a temporal resolution of 20 ms in just 15 heart beats. Images are acquired continuously to resolve cardiac motion.

Results: A short-axis view of the left ventricle (Fig. 2a) shows the excellent myocardium and lipid suppression of fat-suppressed SSFP. Figure 2b shows clear depiction of the right coronary artery. Some artifact due to transient effects is evident in this image. However, a combination of interleaf-ordering [6] and effective transient reduction [5] helps to reduce this artifact.

Discussion: Compared to 2DFT imaging, spiral imaging can achieve similar resolution and FOV with only 30% as many sequence repetitions and with in-plane gradient first-order moments fully nulled. Maintaining the steady state throughout the cardiac cycle is important for achieving good muscle suppression. We have tried various tip angles for the spectral-saturation pulses used for fat-suppression pulses [3]. A flip angle of 180° delays the point of optimal fat-suppression, which further helps to suppress transient image artifacts.

Conclusion: The combination of spiral imaging with fat-suppressed SSFP provides excellent contrast, speed and motion-insensitivity for coronary artery imaging.

References: