# Coronary Artery Imaging at 3T: Reduction of Transient Signal Oscillation and Improvement of Imaging Contrast Using a Magnetization Prepared SSFP Sequence

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**Introduction:** Segmented SSFP (steady-state free precession) sequence has been widely used in coronary MRA. Substantial improvements in signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) have been shown using the technique as compared to a conventional gradient-echo sequence. To minimize cardiac motion induced artifacts, data is typically acquired during the transient phase before a steady-state can be established. Thus signal amplitude shows strong oscillations at the beginning of data acquisition. Various magnetization preparation methods have been proposed to minimize the transient time by applying dummy pulses before data acquisition, such as $\alpha/2$-preparation (1), linear increasing flip angle (LFA) (2), and sinusoidal changing flip angle (SFA) preparation (3). Recently, a TIDE (transition into driven equilibrium) method (4) was used to further improve the initial signal behavior. This technique demonstrated a considerably improved off-resonance behavior. In this study, we modified the TIDE scheme to reduce initial signal fluctuations in coronary artery imaging under off-resonant conditions. At the same time, blood-myocardial contrast was enhanced without applying additional T2-prep pulses. The modified-TIDE (m-TIDE) scheme was tested in healthy volunteers.

**Method:** Sequence: An ECG-gated, segmented 3D SSFP sequence was used for this study. Magnetization preparation pulses included a spectral selective inversion (SPIR) pulse for fat saturation and an m-TIDE dummy train. Figure 1(a) showed a schematic of the m-TIDE scheme, which started with a 90° pulse, after an interval of TR/2, followed by a number of RF pulses with flip angles sinusoidally transiting from 180° to $\alpha_{read}$ (flip angle for data acquisition). The interval between two consecutive dummy pulses was TR with phase alternation of 180°. The flip angle for the $m^{th}$ pulse in a train of n pulse was calculated as:

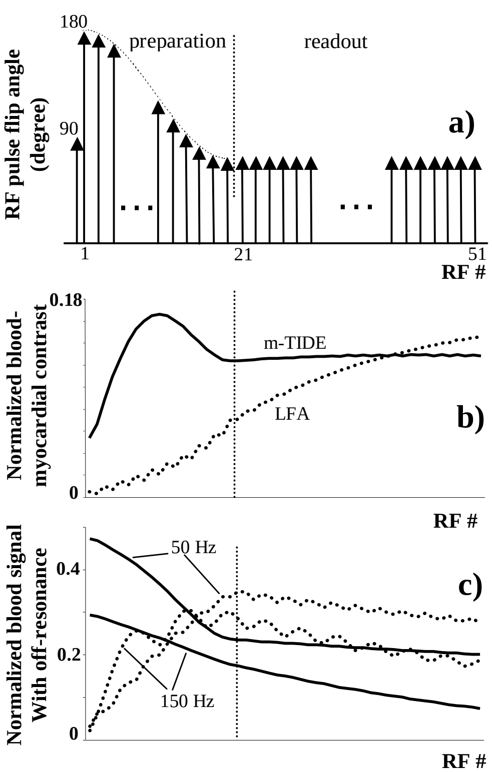
$$\alpha(m) = 0.5 \times (180 - \alpha_{read}) \times \left(1 + \cos\frac{(m-1)\pi}{n-1}\right) + \alpha_{read}$$

Simulations: Numerical simulations were performed on a personal computer using Matlab (Mathworks, Natic, MA). Signal trajectories were calculated using Bloch equations. The blood-myocardial contrast using m-TIDE scheme was compared to corresponding result of a LFA method (5). To compare the signal behavior of these two schemes under off-resonance conditions, blood signal trajectories with 50 Hz and 150 Hz frequency offsets were simulated. Parameters for simulation included TR/TE/$\alpha_{read}$ = 4 ms/2 ms/70°. $T_{1,\,blood}/T_{2,\,blood}$ = 1550 / 180 ms, $T_{1,\,myocardium}/T_{2,\,myocardium}$ = 1115 / 50 ms, n = 20, 31 readout lines / heartbeat.

Coronary artery imaging: Coronary images were acquired from healthy volunteers (n = 4) at a 3.0T (Trio) Siemens whole-body scanner. Separate acquisitions with m-TIDE and LFA prepared were obtained with 3D breath-hold imaging. The maximum possible flip angle ($\alpha_{read}$) was < 70° within the SAR (specific absorption rate) limit. FOV (field-of-view) = 210×350 $mm^2$. Other parameters included: 31 – 35 lines / segment, number of partitions = 6 (interpolated to 12), slice thickness = 3 mm (interpolated to 1.5 mm), matrix size = (124-140)×384, breath-hold time = 24 heartbeats, in-plane resolution = 1.5 – 1.7 × 0.9 $mm^2$.

**Results:** Figure 1(b) illustrates simulated results of blood-myocardial contrast using m-TIDE (solid line) and LFA (dotted line) preparations. Higher contrast is achieved with m-TIDE at the beginning of data readout, when image contrast is largely determined with centric encoding. Improved off-resonance behavior with m-TIDE is illustrated in Figure 1(c). Signal trajectories are smooth using m-TIDE while oscillations are observed with LFA. Simulation results are confirmed by volunteer studies and an example is shown in Figure 2. With improved suppression of background signal (myocardium and fat) using m-TIDE preparation, the left anterior descending (LAD) coronary artery of this subject is well depicted with increased sharpness.

**Discussion:** The m-TIDE scheme has been successfully applied in coronary MRA to reduce transient oscillations of the SSFP signal as well as to improve blood-myocardial contrast. The initial spin-echo like preparation scheme improves $T_2$ weight of the image, which has the potential of suppressing short $T_2$ tissues such as myocardium and fat. At the same time, such a spin-echo like scheme is less sensitive to off-resonance. A major disadvantage of this technique is the increased power deposit, which in turn limits the flip angle of the imaging sequence. However, even in the two studies that we had to decrease the flip angle, good blood-myocardial contrast was preserved. Preliminary results of the study warrant further investigation of this technique in clinical applications.



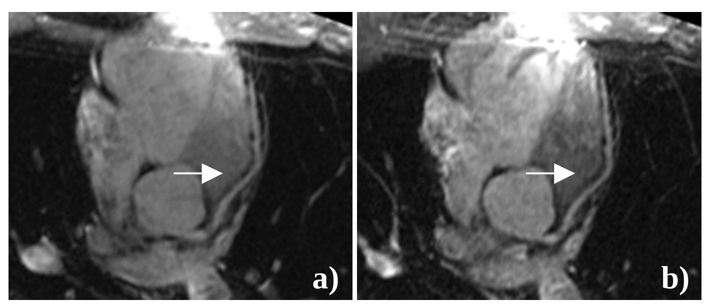




**Figure 2:** LAD coronary image of a volunteer using conventional LFA **(a)** and m-TIDE **(b)** preparing schemes. Note the improved suppression of background tissues (myocardium and fat) and increased sharpness of LAD in **(b)** as indicated by arrows.

**Figure 1: (a).** Schematic of the m-TIDE preparation. Note the interval between 90° and 180° pulses is TR/2 and the data readout starts from the $21^{th}$ RF pulse.
**(b).** Normalized blood-myocardial contrast is increased with m-TIDE (solid line) as compared to that from LFA (dotted line) preparation; **(c).** m-TIDE shows smooth signal transition even with 50 Hz and 150 Hz off-resonance, while signals with LFA preparation show significant fluctuations under the same conditions.

**References:**
1. Deimling M et. Al. Proc. ISMRM 2, p495, 1994 2. Nishimura DG et. Al. Proc. ISMRM 7, p301, 2000 3. Paul D et. al. Proc. ISMRM 11, p2663, 2004 4. Hennig J et. al. MRM 48: 801-809 5. Deshpande VS et al. Proc. ISMRM 10, 2002