High-Resolution Coronary MR Angiography with Outer Volume Suppression/T_2 Preparation

Nii Okai Addy[1], Jieying Luo[1], Bob S Hu[2], and Dwight G Nishimura[1]
[1]*Electrical Engineering, Stanford University, Stanford, CA, United States,* [2]*Cardiovascular Disease, Palo Alto Medical Foundation, Palo Alto, CA, United States*

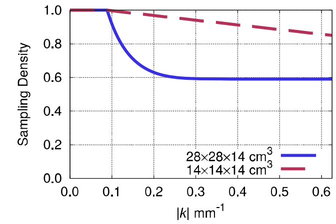

Figure 1: The variable-density sampling functions for the full- and reduced-FOV trajectories.

Target Audience: MR engineers and physicists interested in coronary angiography and trajectory design.

Purpose: For whole-heart coronary MR angiography (CMRA), reduced-FOV methods are of potential benefit because the heart occupies only a portion of the chest. CMRA methods typically spend time to encode a field-of-view (FOV) larger than the heart to avoid aliasing artifacts. In addition, motion from the surrounding regions can lead to artifacts. For reduced-FOV imaging, we have developed a combined outer volume suppression (OVS), T_2-preparatory (T_2-Prep) sequence to provide 2D spatial selectivity while simultaneously enhancing blood-myocardium contrast [1]. This OVS/T_2-Prep sequence can be used to shorten the minimum scan time by reducing the FOV of the imaging sequence; alternatively, it can be used to enable higher resolution imaging without prolonging the scan time. The purpose of this work was to integrate OVS/T_2-Prep with a high-resolution CMRA sequence that we have recently developed that is based on a variable-density (VD) 3D cones trajectory. The OVS/T_2-Prep sequence facilitates such high-resolution parallel imaging by reducing the required acceleration factor.

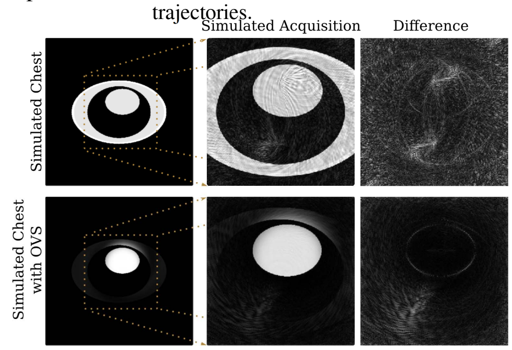

Figure 2: Simulated gridded images (center column) of 3D phantoms (left column) with full-FOV (top) and reduced-FOV (bottom) VD trajectories. OVS was also included in the reduced-FOV case. Difference images (right column) compare the simulated phantom to gridded images.

Methods: The OVS/T_2-Prep sequence [1] was comprised of a $\pi/2$ BIR4 tip-down pulse followed by two adiabatic full passage refocusing pulses and a $-\pi/2$ 2D spiral tip-up pulse designed to excite an elliptical 16×12 cm^2 region. For high-resolution imaging, we previously developed a VD 3D cones trajectory encoding a 28×28×14 cm^3 FOV with 0.8 mm isotropic spatial resolution [2]. Parameterized by a 10th order polynomial, relative trajectory sampling density decreased from 1.0 at 0.9 cm^{-1} to 0.59 at k_{max}, resulting in an acceleration factor of 2.9. With OVS/T_2-Prep, the FOV was reduced to 14×14×14 cm^3, thereby lowering the required acceleration factor to 1.3 using the same number of readouts as the previous VD trajectory. With OVS, the relative trajectory sampling density decreased linearly from 1.0 at 0.9 cm^{-1} to 0.85 at k_{max}. The sampling densities are displayed in Fig. 1.

To examine the effect of OVS, a simulated 3D phantom was generated to model the heart. Gridding reconstruction was simulated with the full-FOV VD and reduced-FOV VD trajectories. For the reduced-FOV case, OVS was modeled through Bloch equation simulation and applied to the simulated phantom.

CMRA scans were performed on a 1.5 T GE Signa Excite scanner equipped with an 8-channel cardiac coil. The original VD cones trajectory without OVS (full FOV) was compared with the new VD trajectory with OVS (reduced FOV). OVS/T_2-Prep (T_2-Prep time = 20 ms) preceded SSFP imaging with VD 3D cones. For motion correction, 3D translational motion was tracked using orthogonal 2D image-based navigators. Fat suppression was achieved using an alternating-TR SSFP sequence with $TE/TR_1/TR_2$ = 0.6/1.15/4.3 ms. Motion-corrected images were iteratively reconstructed using L_1-ESPIRiT with motion-weighted processing [3].

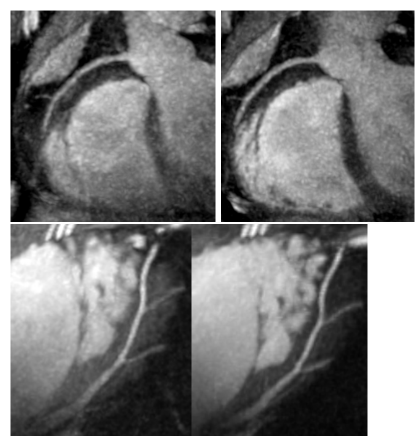

Figure 3: Reconstructed maximum intensity projection images of the RCA (top row) and LAD (bottom row). Comparison of full FOV (left column) and reduced FOV (right column) trajectories in two volunteers.

Results: As shown in Fig. 1, OVS enables the use of a more uniformly sampled *k*-space trajectory through reduced-FOV imaging with a lower acceleration factor. Figure 2 illustrates the ability of OVS/T_2-Prep to reduce aliasing artifacts with the lower acceleration factor. Figure 3 shows the comparative results from two volunteer scans, each acquired in approximately 10 min. The images display a clean visualization of the right coronary artery (RCA) and left anterior descending artery (LAD) along with some small branches.

Discussion/Conclusion: The use of OVS/T_2-Prep lowers the acceleration factor to facilitate parallel imaging. The suppression of static structures not of interest helps avoid possible aliasing and motion artifacts. With OVS/T_2-Prep and reduced acceleration factors, further increases in spatial resolution may be possible.

References: [1] Luo J, et al., Proc. 22nd ISMRM, p. 950. 2014. [2] Addy NO, et al., Proc. 22nd ISMRM, p. 2506. 2014. [3] Uecker M, et al., MRM 2013.