Three-Dimensional Time-Resolved Whole-Heart Coronary Angiography using a 3D Cones Trajectory

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Introduction Whole-heart MRI is an effective method for imaging the coronary arteries. Previous work has used Cartesian [1] and radial [2] techniques with balanced SSFP, which provide good results but suffer from low readout duty cycles, long cardiac windows, and require parallel imaging reconstructions or undersampling to reduce scan time. These problems result in reduced SNR and reduced robustness of the methods. We use the 3D Cones [3] trajectory to implement a whole heart imaging sequence with excellent spatial (1.1 mm isotropic) and temporal (60 ms) resolution that is SNR-efficient and robust to motion.

Methods A trajectory design algorithm optimized for short-readout 3D Cones was used to generate the set of readout gradients. A specially-designed 0.9 ms, 50^o flip angle 2D echo planar RF excitation using VERSE [4] was used to excite a 14 cm (A-P) x 20 cm (S-I) profile. This pulse effectively suppresses both the chest wall and the shoulders/abdomen in steady-state. Myocardial suppression is generated by maintaining the SSFP signal over the entire cardiac cycle. Fat suppression is achieved by using a TE = TR/2-1.2 ms (Fig. 1), which at 1.5 T puts fat and water in quadrature. The steady-state is briefly interrupted (Fig. 2) to acquire one navigator image per heartbeat. Maintaining such a steady-state (as opposed to using separate T2-prep or fat suppression pulses) allows several temporal frames with the same contrast to be acquired throughout diastole. We acquire 8 frames with 16 readouts (60 ms) per frame. These frames can be reconstructed using a sliding window and shown as a video. A total of 14,000 readouts were required to achieve a FOV of 20 cm. Using a DVA [5] overscan of 10%, this takes about 960 heartbeats (14 minutes). The sequence was run on a GE Excite 1.5T scanner with an 8 channel coil. A low-resolution 3D coil phase map was obtained and used to correct for the phase of each coil before running a sum of squares gridding reconstruction.

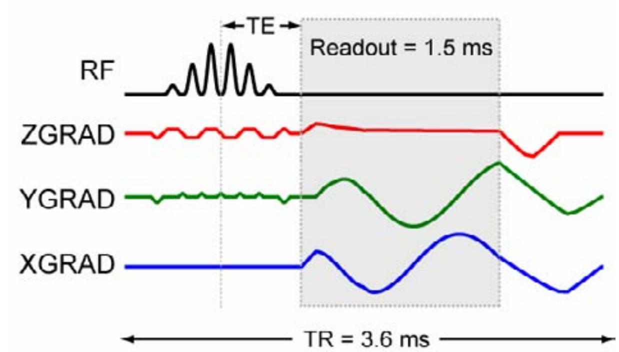

Figure 1: *The SSFP sequence consists of a 2D echo planar VERSE RF pulse, followed by the 3D Cones readout. The TE is set to TR/2-1.2 ms so that fat and water are in quadrature at the start of the readout.*

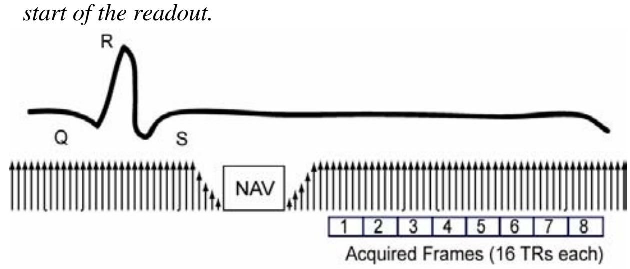

Figure 2: *The steady state is maintained throughout the entire heart cycle and is briefly interrupted to acquire a navigator. Eight temporal frames (16 TRs each) are acquired in mid-diastole.*

Results Slices from one of the temporal frames are shown in Fig. 3 and Fig. 4. The method results in excellent time resolved whole-heart images. Significant motion of the RCA during diastole can be seen in the videos, which emphasizes the importance of high temporal resolution.

Discussion The 3D Cones trajectory is ideally suited to this application because of its zero prep time and its ability to flexibly increase readout length in exchange for reduced scan times, higher readout duty cycle and improved SNR efficiency. The efficiency and robustness of the 3D Cones trajectory allows imaging of the coronary arteries with very high temporal and spatial resolution in a reasonable scan time (14 min). Undersampling the 3D Cones trajectory (perhaps in combination with parallel imaging techniques) may lead to further dramatic decreases in scan time.

References [1]Weber, MRM2003, [2]Stehning, MRM2004, [3] Irarrazaval MRM1995, [4]Hargreaves MRM2004, [5] Sachs MRM1995

Figure 3: *Coronal slice showing whole heart coverage. Right system blood is bright since it is arriving from regions not excited by the RF pulse.*

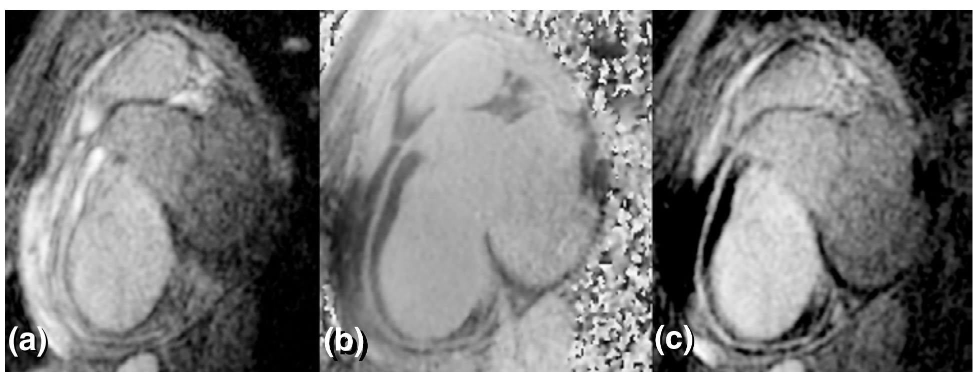

Figure 4: *Left Anterior Oblique slice from one temporal frame of the 3D dataset showing the right coronary artery. The (a) magnitude, (b) phase, and (c) real part of the image are shown. The epicardial fat surrounding the RCA is completely suppressed by removing the imaginary component of the image. Signal from the chest wall is well suppressed by the 2D RF pulse.*