128-channel highly-accelerated breath-held 3D coronary MR Imaging

A. Shankaranarayanan[1], M. Fung[2], P. Beatty[1], D. Blezek[3], T. Foo[3], L. Marinelli[3], R. Giaquinto[3], R. Darrow[3], E. Fiveland[3], E. Schmidt[4], and C. J. Hardy[3]
[1]Global Applied Science Lab, GE Healthcare, Menlo Park, CA, United States, [2]Global Applied Science Lab, GE Healthcare, Bethesda, MD, United States, [3]Global Research Center, GE Healthcare, Niskayuna, NY, United States, [4]Global Applied Science Lab, GE Healthcare, Boston, MA, United States

Introduction: Compared to the gold standard, X-ray angiography, and CT angiography (CTA), MRI coronary artery imaging (CAI) is still attractive due to the lack of harmful ionizing radiation or the need for large volumes of iodinated contrast agent. Common coronary artery imaging protocols are based on segmented 2DFT or 3DFT gradient-echo acquisitions with cardiac gating, breath-holding and/or respiratory navigation [1], using different forms of parallel imaging to reduce the imaging window in the cardiac (QRS) cycle or to reduce the scan time [2]. Reduction in the cardiac imaging window per QRS cycle reduces the amount of motion that occurs during acquisition, especially at higher heart rates, while reduction in the total imaging time may reduce the possibility of end-expiratory position drift and/or the possibility of the heart not returning to the same spatial position in successive cardiac cycles. Recently, image acquisition using a 128-channel MR system and a high-density 128-element receiver-coil array was demonstrated [3]. Substantial improvement in g-factor performance, as well as a ~20% improvement in SNR around the center of the coil array, over a similarly designed 32-element array, was shown.

In this work, we demonstrate 3D whole heart imaging specifically targeted towards CAI with a highly accelerated breath-hold acquisition on a 128-channel system. This combination may enable greater reliability high-resolution CAI due to the possibility of simultaneously reducing, both the window in the cardiac cycle, and the total acquisition time.

Figure 1. Flexible 64-element anterior RF coil array, with covers removed, on a subject lying on the 64-element posterior array.

Methods: Data were acquired on a prototype 128-receiver-channel 1.5 T CV/i MRI system (GE Global Research, Niskayuna, NY) using a 128 channel torso array with 64-elements in the anterior and posterior sections [3]. Each section comprised of a hexagonal lattice of 6.4 cm diameter coils covering a 40 cm x 47 cm surface with the coils overlapped to minimize nearest neighbor coupling (Figure 1). A 3D Cartesian balanced-SSFP (FIESTA) pulse sequence was customized to synchronize the prospectively ECG-gated acquisition for all 128 channels.3D SSFP pulse sequence parameters were: matrix=256x256 points, interpolated to 512x512, bandwidth=±125 kHz,. TE/TR/θ=1.6/3.5ms/55°, FOV=43x43cm. An entire phase-encode (ky) line, for a given slice-encode, was covered in 1 (1RR version) or 2 (2RR version) cycles, which, lacking acceleration, would have resulted in an imaging window of 768 or 384ms, respectively, far too long to prevent motional blurring. The partition thickness was 2.6 mm, with 50 (2RR) or 70 (1RR) slices prescribed, encompassing an S-I volume of 12-14 cm to cover the entire heart. Nominal voxel size was (1.6 x1.6x2.6) mm^3, interpolated to (0.8x0.8x1.3) mm^3 for large-volume acquisitions. Fat suppression was achieved with a spectrally selective RF inversion pulse (SPECIAL). The un-aliased images were reconstructed using the Autocalibrating Reconstruction for Cartesian sampling (ARC) method [4] with externally acquired calibration data. The calibration data for ARC was acquired in a separate 4 sec breath-held scan. Acceleration factors up to 16 (4 slice-encode x 4 phase-encode) were tested. The quiescent systolic or diastolic phase of the cardiac cycle was determined in a separate 2D CINE scan, and this value was used for proper trigger delay timing.

Healthy volunteers were scanned after receiving written informed consent in accordance with IRB-approved protocols. . A typical 3D unaccelerated breath-held (21-27 sec) CAI protocol was optimized to provide complete heart coverage (12-14cm). Acceleration factors were then optimized to meet breathhold scan time constraints, while adjusting the partition thickness for improved spatial resolution. The images were qualitatively inspected for g-factor induced noise.

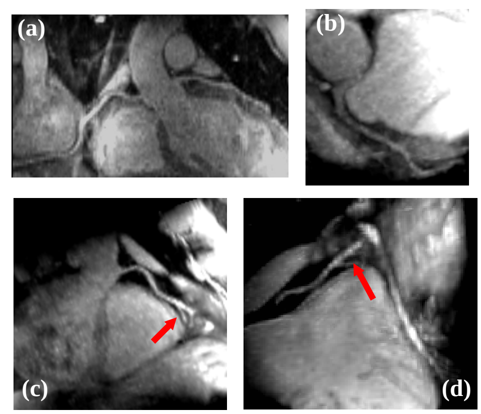

Figure 2. Volunteer results. 1RR case: (a) RCA (b) Left Main and Proximal LAD. 2RR case: (c) and (d) are RCA. Note that the coronaries are sharper in the 2RR case. The arrows show some distal branches.

Results: Figure 2 shows reformats of the RCA (2a), as well as the Left Main and Left Anterior Descending (LAD) (2b) in a volunteer with a heart rate of 55 bpm. A 1RR, 12-fold acceleration was utilized in this study. Figures 2c and 2d show RCA from a 2RR acquisition. Note the lack of motional blurring in the aorta, the strong coronary vessel conspicuity, sharp vessel borders, with even some distal branches visualized in both cases but to a higher degree in 2RR case. The temporal window in 2RR case was 110ms, while in 1RR case it was 210ms. No pronounced g-factor-related noise amplification was seen. Such acceleration factors allowed large z-coverage (14cm) at scan times of 21-27s.

Discussion:

The ability to achieve high acceleration factors with large-element arrays enables whole heart coronary artery imaging to be performed with high spatial and temporal resolution within the stringent time constraints of clinical breath-held scanning. The reduced g-factor noise and the excellent SNR demonstrated in these images suggest that 128-channel arrays enable motion-artifact reduction by substantial reduction of the acquisition window in each cardiac cycle, and/or by reducing the overall breath-hold time. This allows flexibility to choose acquisition parameters to optimize spatial resolution or temporal resolution, or both.

References:

[1] Kim WY et al. NEJM 2001; 345:1863–1869. [2] Neindorf T et al MRM 2006; 56:167-176. [3] Hardy CJ et al. ISMRM 2007, p244. [4] Beatty et al. ISMRM 2007, p1749.