Contrast-Enhanced Whole-Heart Coronary MRA at 3T using Gradient Echo Interleaved EPI and single dose of Gd-BOPTA

H. Bhat[1], S. Zuehlsdorff[2], R. Jerecic[2], and D. Li[1]

[1]Radiology and Biomedical Engineering, Northwestern University, Chicago, IL, United States, [2]Siemens Medical Solutions, Chicago, IL, United States

INTRODUCTION: Whole-heart coronary MRA is challenging due to the relatively long data acquisition time on the order of 10-15 minutes. Drifts in diaphragm position, patient motion and heart rate variations over this long imaging time may compromise the robustness of whole-heart coronary MRA and result in image artifacts. Gradient echo interleaved EPI (GRE-EPI) [1] is a method which can provide significant speed gain and has previously been reported for volume-targeted imaging at 1.5T [2, 3]. The purpose of this work was to optimize a GRE-EPI acquisition scheme for reducing the imaging time of whole-heart contrast-enhanced coronary MRA at 3T. A previous study [4] used slow infusion (0.3 cc/sec) of a double dose (0.2 mmol/kg) of high relaxivity contrast agent, gadobenate dimeglumine (Gd-BOPTA, Multihance, Bracco) with a conventional gradient-echo sequence for whole-heart MRA. In this study, we used slow infusion (0.3 cc/sec) of a single dose (0.1 mmol/kg) of Gd-BOPTA. This was possible due to the shortened imaging time with GRE-EPI.

METHODS:

Sequence Design Considerations: 6 echoes (TR = 10.6 ms) were acquired after each RF pulse with the 2nd echo sampling the central k-space region (TE = 3.5 ms). This asymmetric k-space sampling (partial Fourier factor of 6/9) minimized off-resonance and flow artifacts. Homodyne reconstruction was used to synthesize the unacquired k-space region [5]. The k-space amplitude modulations due to non-steady state conditions were minimized by appropriate selection of the TI and flip angle using simulations of the Bloch equations and phantom studies. To further reduce the imaging time, GRAPPA (acceleration factor = 2) was used. To avoid different traversal velocities in the low and high frequency k-space regions the reference lines were acquired using a separate gradient echo scan prior to the whole-heart scan. The reference lines were acquired in 4-5 seconds with a spatial resolution of 4 x 4 x 4 mm3. First order phase correction was used to align the even and odd echoes. At 3T, the off-resonance phase interferes with accurate estimation of the phase correction parameters. A "dual reference scan" method [6] which acquires 2 sets of reference lines with opposite readout gradient polarities was used to overcome this problem. Since each echo in the two sets of reference lines has the same TE, the off-resonance phase is the same and can be eliminated, leading to accurate determination of the linear phase parameters. Fig 1 shows the linear and constant phase difference between the even and odd echoes for a phantom, with the imaging frequency set to the water (blue) and fat (red) frequencies. For both acquisitions the phase factors are identical, showing the robustness of the method in the presence of off-resonance effects.

Volunteer Imaging: 4 volunteers were scanned on a 3T scanner (MAGNETOM Trio, Siemens AG Healthcare Sector, Erlangen, Germany). Scan parameters were: flip angle = 25, 36 to 72 lines per heartbeat in a window of 64 to 128 msec depending on the coronary resting period, readout bandwidth = 1221 Hz/pixel, non selective inversion recovery (IR) pulse with TI = 350 ms, true voxel size: 1 × 1 × 2 mm3. 0.1 mmol/kg body weight of Gd-BOPTA was injected at 0.3 cc/sec. To maximize SNR, a previously described self-triggering method [7] was used to acquire the central k-space views during peak blood signal enhancement. The total imaging time for the whole-heart scan was 1 minute (for a heart-rate of 60 without navigator gating). For comparison, the same sequence was run with adiabatic T2-preparation [8] (T2prep) before contrast was injected. The SNR, CNR, image quality scores (1, poor; 2, fair; 3, good; 4, excellent) and lengths of the coronary arteries visualized by the 2 techniques were compared.

RESULTS: The average imaging time for contrast-enhanced whole-heart imaging was 3.0 ± 0.7 minutes with an average navigator efficiency of 43 ± 8.6 %. Fig. 2 shows images of the LAD using the dual and single reference scan methods. The blurring in the LAD using the single reference scan method is removed by the dual reference scan method (red circles). Fig. 3 shows coronary artery images from 2 volunteers using the GRE-EPI acquisition with IR and contrast (left) and T2prep and no contrast (right). Vessel visualization, SNR and CNR are markedly improved after contrast injection. Quantitative comparison between the 2 sequences is shown in Table 1.

CONCLUSION: A GRE-EPI sequence was optimized for contrast-enhanced whole-heart coronary MRA at 3T using slow infusion of a single dose of Gd-BOPTA. In volunteers, all the major coronary arteries were clearly depicted in an average scan time of 3 minutes. This represents more than a factor of 2 reduction in both the scan time and contrast dose from previous studies. Single dose reduces the risks associated with contrast media as compared to double dose.

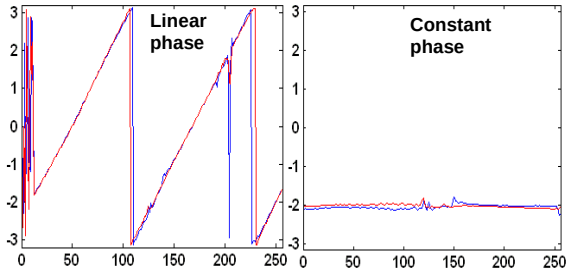

Fig 1. *Linear (left) and constant (right) phase correction parameters obtained in a phantom from the dual reference scans for imaging frequency set to the water (blue) and fat (red) resonances.*

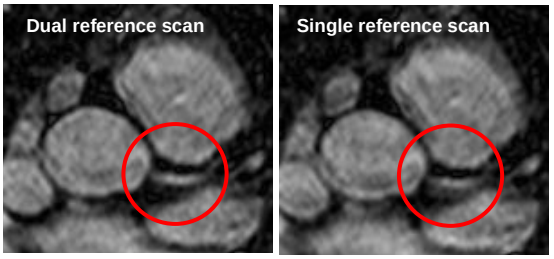

Fig 2. *LAD image in a volunteer with the GRE-EPI sequence using dual reference scans (left) and a single reference scan (right).*

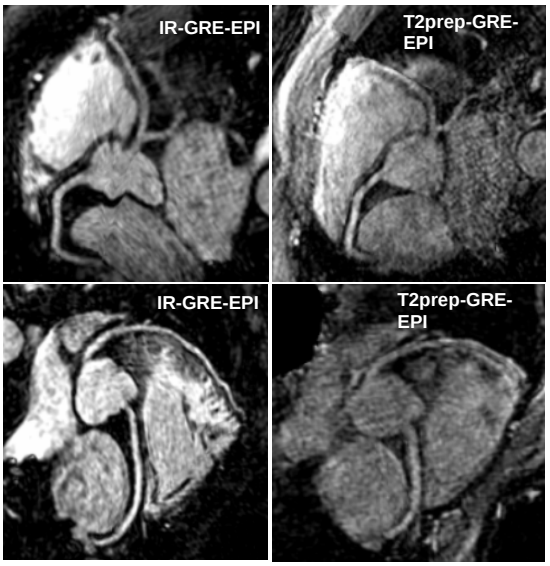

Fig 3. *Coronary artery images in 2 volunteers with the GRE-EPI sequence using IR with contrast (left) and T2prep without contrast (right)*

REFERENCES: [1] MRM 30:609-16 [2] JMRI 13:676-81 [3] JMRI 10:21-25 [4] MRM 58:1-7 [5] IEEE Trans Med Imag 10(2):154-63 [6] JMRI 9:847–52 [7] ISMRM 2008 914 [8] MRM 55:858–64.

Table 1*. Comparison between the GRE-EPI techniques using IR with contrast and T2prep without contrast*

GRE-EPI Sequence	SNR	CNR	Imaging time	Navigator efficiency	Image quality score	RCA length	LAD length
IR with contrast	28.8± 5.8	16.3± 5.8	3 ± 0.7	43 ± 8.6	3.1 ± 0.4	10.1 ± 2.3	12.5 ± 2.6
T2prep	14.8± 0.9	4.9± 1.3	3.3 ± 0.7	42.3 ± 11.5	1.5± 0.0	9.1 ± 1.9	8.7 ± 3