Contrast-enhanced whole-heart coronary MR angiography at 3.0 T: comparison to steady-state free precession imaging at 1.5 T

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Introduction: Steady-state free procession (SSFP) sequence (e.g., TrueFISP) has gained great success in cardiac imaging at 1.5 T due to its intrinsic high blood signal intensity and blood-myocardial contrast [1]. However, the increased B_1 field inhomogeneity, frequency offset from tissue susceptibility variation and special absorption rate (SAR) limit the consistency of SSFP in acquiring high quality coronary artery images at 3.0 T [2,3]. Spoiled gradient-echo sequence (e.g., FLASH) has better tolerance to field inhomogeneity. SAR is no longer a major issue due to the use of low flip angle radio-frequency pulse. However, a major drawback of coronary MRA with FLASH is that the signal-to-noise ratio (SNR) of coronary arteries and the blood-myocardial contrast are not as high as those from balanced SSFP readout [4]. T_1-shortening contrast agents have been used for coronary MRA to overcome the limitations at 3.0 Tesla. Recently, contrast-enhanced whole-heart coronary MRA using slow infusion of high-relaxivity extravascular contrast agent has been shown to be a promising technique for imaging coronary arteries at 3.0 T [5].

The purpose of this study was to compare contrast-enhanced whole-heart MRA at 3.0 T with SSFP coronary MRA at 1.5 T. SNR, contrast-to-noise ratio (CNR), and vessel delineation were compared based on data sets acquired from same volunteer group at both field strengths.

Methods: Eleven healthy volunteers (10 men and 1 woman aged 33 - 65 years, mean age 51 years) were recruited for this study and each subject underwent both 3.0 T and 1.5 T coronary MRA in random order within two weeks. No beta-blocker or nitroglycerine was administrated in any of these imaging sessions. SSFP whole-heart coronary MRA was performed on a 1.5 T scanner (MAGNETOM Avanto, Siemens Medical Solutions) with a respiratory-gated, ECG-triggered, fat saturated, segmented 3D TrueFISP sequence. T_2 preparation (40 msec) was applied to improve the blood-myocardium contrast. Parallel imaging (GRAPPA factor of 2) was applied in the phase-encoding direction to accelerate data acquisition. 56-72 transverse slices were acquired and interpolated to 112-144 slices of 0.9 mm thickness. The imaging parameters were as follows: TR = 3.7 ms, TE = 1.7 ms, flip angle = 90º, readout bandwidth = 870 Hz/pixel, lines per heartbeat = 30 – 40, Voxel size = $1.4 \times 1.4 \times 1.8$ mm^3 interpolated to $0.7 \times 0.7 \times 0.9$ mm^3. Contrast-enhanced whole-heart coronary MRA was performed on a 3.0 T scanner (MAGNETOM Trio, Siemens Medical Solution) with a respiratory-gated, ECG-triggered, fat saturated, segmented 3D FLASH sequence. The 3D k-space data was collected with a centric ordering scheme in the phase-encoding direction and linear order in the partition-encoding direction. In addition, a non-selective inversion pulse (TI = 200 msec) was applied prior to the navigator-echo pulses to suppress the background signal. 56-72 slices were acquired and interpolated to 112-144 slices of 0.9 mm thickness. GRAPPA was used in the phase-encoding direction with an acceleration factor of 2. Other imaging parameters include TR = 3.0 ms, TE = 1.4 ms, flip angle = 20º, lines per heartbeat = 30-40, readout bandwidth = 610 Hz/pixel. Voxel size = $1.4 \times 1.4 \times 1.8$ mm^3 interpolated to $0.7 \times 0.7 \times 0.9$ mm^3. 0.2 mmol/kg body weight of MultiHance (Bracco Imaging SpA, Milan, Italy) was slowly injected at a rate of 0.3 ml/sec, followed by a chaser of 20 ml saline at the same rate. Data acquisition started 60 seconds after the initialization of contrast administration.

SNR, CNR, scores of image quality (1=poor, 2=fair, 3=good, 4=excellent), and coverage of coronary segments (15 coronary segments according to the classification of the American Heart Association) were analyzed and results from these two techniques were statistically compared.

Results: Two volunteers were excluded for analysis because the heart rate was significantly different at two imaging sessions. The mean heart rate of the other 9 volunteers for 3.0 T and 1.5 T coronary MRA was 68±10 bpm and 63±6 bpm, respectively ($p > 0.05$). The average acquisition time of 3.0 T coronary MRA was significantly shorter than that of 1.5 T coronary MRA (9.7±2.3 versus 14.6±3.5, $p < 0.05$). The overall SNR was lower at 3.0 T than at 1.5 T (34.7±7.5 versus 43.4±8.8, $p < 0.05$), whereas the overall CNR was higher at 3.0 T than at 1.5 T (30.2±6.1 versus 18.8 ± 2.6, $p < 0.01$). The average number of coronary segments visualized from 3.0 T images was greater than that from 1.5 T (10.4±3.5 versus 8.5±2.5, $p < 0.05$). Image quality was similar at 3.0 T and 1.5 T (2.8±0.96 versus 3.0±1.03, $p > 0.05$).

Conclusions: Contrast-enhanced whole-heart coronary MRA at 3.0 T demonstrated higher CNR, less acquisition time, and better depiction of coronary segments compared to SSFP coronary MRA at 1.5 T. Patient studies are required to evaluate the clinical value of the technique.

References: 1. Manning WJ, et al. Cariol Clin. 2007;25:141-170. 2. Stuber M, et al. Magn Reson Med. 2002;48:425-429 3. Sommer T, et al. Radiology. 2005;234:718-725. 4. Maintz D, et al. Am J Roentgenol. 2004;182(2):515-521. 5. Bi X, et al. Magn Reson Med. 2007;58:1-7

Figure 1. Multi-planar reformatted images of a 53-year-old male healthy volunteer show higher contrast-to-noise ratio (CNR) in left anterior descending coronary artery (arrow) on contrast-enhanced coronary MRA at 3.0 T (right) than that on non-contrast SSFP imaging at 1.5 T (left).

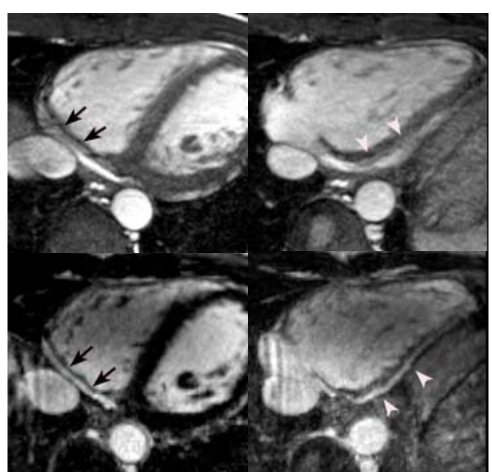

Figure 2. Maximum intensity projection images of a 33-year-old male volunteer show the distal portion of right coronary artery (arrow) and posterior descending coronary artery (arrowhead) are not clear at 1.5 T images (top row), whereas these vessels were clearly depicted at 3.0 T images with effective suppression of background signal from pericardiac fluid and myocardium (bottom row).