

Whole-heart Coronary MR Angiography with 2D Parallel Imaging: Comparison of Two Cartesian Sampling Schemes with and without CAIPIRINHA Reordering

Xiaoming Bi¹, Randall Kroeker², Johannes Breuer³, Sven Zuehlsdorff¹, and Peter Kellman⁴

¹Siemens Healthcare, Chicago, IL, United States, ²Siemens Healthcare, Winnipeg, Canada, ³Siemens AG Healthcare, Erlangen, Germany, ⁴National Institute of Health, Bethesda, MD, United States

Introduction: Whole-heart coronary MRA continues to be a time consuming procedure due to the demanding requirements for high spatial resolution, large volume coverage, and the need for physiological gating. Parallel imaging shortens acquisition time but such acceleration is limited to factor of 2-3 in routine exams. With increased availability of high density array coils, improved sampling strategies and image reconstruction techniques, 2D acceleration of volumetric data acquisition becomes practical [1]. Previous work demonstrated improved parallel imaging reconstruction using a modified sampling strategy, namely 2D CAIPIRINHA [2]. By shifting sampling points from their normal positions in a controlled manner, coil sensitivity variations were efficiently exploited. The purposes of this study are two-fold: 1) investigate the feasibility of whole-heart coronary MRA in consecutive volunteer studies with 2D CAIPIRINHA sampling; 2) compare results of 2D CAIPIRINHA to those acquired with conventional Cartesian sampling scheme.

Methods: Five healthy subjects (age: 37.8 ± 3.7 yrs, weight: 171 ± 21 lbs) with informed consent were imaged on a 1.5T whole-body scanner (MAGNETOM Espree, Siemens AG Healthcare, Germany) using 32-channel receiver coils (InVivo Corporation, USA). For each subject, coronary MRA images were acquired with conventional and CAIPIRINHA sampling schemes (Fig. 1), respectively, in random order. Parallel imaging factor of 8 (PE x PAR = 4×2) was employed with separate reference lines (32×32) acquired at the start of each 3D measurement. For CAIPIRINHA reordering, every other PE line was shifted by 1 sample in the PAR direction (Fig. 1b). Imaging parameters were identical for the conventional and CAIPIRINHA sampling schemes. To fully explore the coil geometry, PE was prescribed in the left-right direction with 100% oversampling and PAR was placed in the head-foot direction with 20% oversampling. Typical imaging parameters included: FOV = 24×24 cm²; matrix = 192×192 ; acquisition voxel size = $1.3 \times 1.3 \times 1.3$ mm³ without interpolation or partial Fourier in the PE and PAR directions; flip angle = 90°; TR/TE = 3.7/1.7 msec; balanced SSFP readout with 40 ms T2 preparation. Data acquisition was synchronized to mid-diastole (24-32 lines/heart beat). Navigator-gating was utilized for respiratory-gating with ± 2.5 mm acceptance window.

Parallel image reconstruction used auto-calibrating GRAPPA and a kernel size of 5/4/6 (kx/ky/kz). Parallel imaging g-maps were generated inline as part of the reconstruction routine. For comparison, g-factors were measured for both sampling schemes in a matched ROI covering the heart.

Results: Coronary MRA was successfully acquired from all subjects using both conventional and CAIPIRINHA sampling strategies. Figure 2 illustrated representative coronary artery images acquired from different subjects. Coronary vessels were sharply delineated in all views reformatted from isotropic datasets. Average imaging time was 7.5 ± 0.5 minutes with large 145 mm coverage in the head-foot direction. Figure 3 demonstrated reduced coil geometry factors and visually improved SNR using CAIPIRINHA reordering compared to corresponding images acquired with conventional reordering. Both sampling schemes resulted in relative low g-factors – average values were 1.85 ± 0.17 and 1.52 ± 0.05 , respectively, for the conventional and CAIPIRINHA reordering (one-tailed t-test $p = 0.038$).

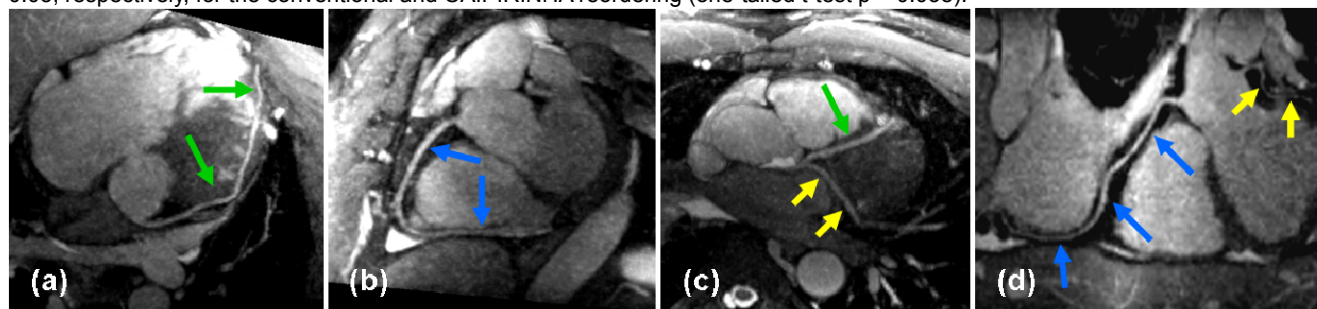


Figure 2. MIP (a, b, c) and curved MIP (d) images of coronary arteries from different subjects acquired with CAIPIRINHA reordering. With 1.3 mm³ isotropic spatial resolution, left anterior descending (green arrows), left circumflex (yellow arrows) and right coronary arteries (blue arrows) were sharply delineated in all reformatted views.

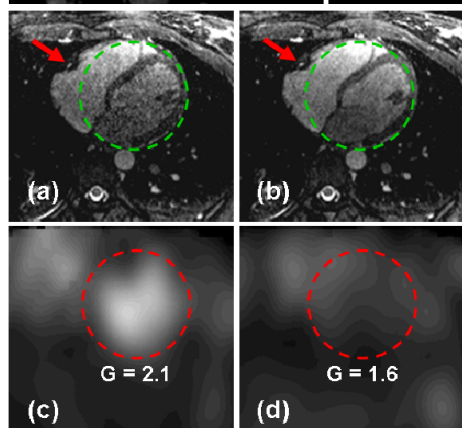


Figure 3. One selected partition and corresponding g-maps of whole-heart measurements using conventional (a, c) and CAIPIRINHA (b, d) reordering. Cross section of right coronary artery (red arrows) was well depicted in both image (a) and (b). Note substantially reduced g-factor (red circles) and visually improved SNR (green circles) in the heart with CAIPIRINHA. Image pairs were displayed in the same window level setting.

Discussion and Conclusions: Good quality coronary artery images were consistently acquired across subjects despite high acceleration factor utilized in this study. This is largely due to well-conditioned coil geometry with reference to the prescription imaging volume, optimized excitation profile and reconstruction routine. In this pilot study of 5 subjects, g-factors from CAIPIRINHA were lower than corresponding values from using conventional sampling scheme. This warrants further comparison of these two sampling schemes in a large patient cohort.

References: [1] Niendorf T et al, MRM 56: 167; 2006 [2] Breuer FA et al, MRM 55: 546; 2006