Whole-Heart Coronary MRA with High SENSE Factors

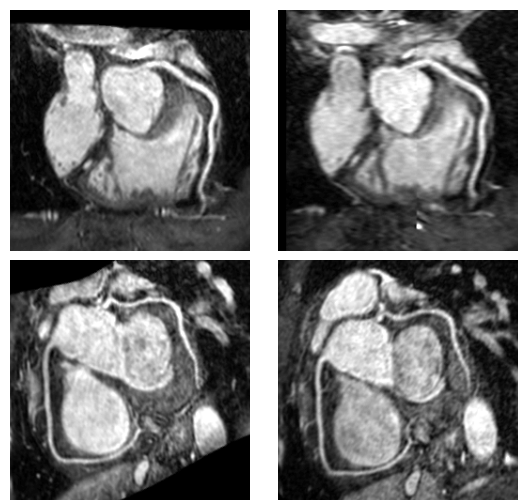
O. M. Weber[1], A. J. Martin[1,2], C. B. Higgins[1]
[1]University of California, San Francisco, San Francisco, CA, United States, [2]Philips Medical Systems, Best, Netherlands

Introduction: Whole-heart coronary magnetic resonance angiography (MRA) by means of magnetization-prepared, navigator-gated, steady state free precession (SSFP) MRI has been shown to be a valuable alternative to the acquisition of a series of individual volumes, each one targeting a different coronary artery in a separate scan [1]. In a scan time comparable to the time needed for two targeted volume scans, all the coronary vessels were imaged with similar image quality, but improved coronary coverage and with easier setup. However, with resulting scan times of more than ten minutes, the method is susceptible to patient motion and respiratory drift. Use of higher reduction factors in combination with parallel imaging techniques (such as sensitivity encoding, SENSE) can considerably reduce scan times. Due to the high number of slices and the considerable slab thickness, the whole-heart approach seems especially well suited for higher SENSE factors by using 2D-SENSE (combining parallel imaging in phase-encoding and slice-selective directions). It was the goal of this work to explore 2D-SENSE with high acceleration factors in whole-heart coronary MRA.

Methods: Experiments were performed on a 1.5T Intera I/T system (Philips Medical Systems, Best, the Netherlands) with a 5-element cardiac synergy coil. Eight normal volunteers (one woman, seven men; mean age, 35.0±8.7 years) were enrolled in the study. Prior to the coronary MRA's, a cine MRI with 50 heartphases of a four-chamber view was performed using a SSFP sequence during a single breathhold. On this data set, the optimal diastolic acquisition window for subsequent high-resolution coronary scans was visually determined. Two magnetization-prepared (T2-preparation pulse [2], fat saturation pulse), free-breathing, SSFP whole-heart acquisitions were performed: 1) An axial volume, consisting of 140 slices, slice thickness 0.75 mm, SENSE=2 in phase-encoding (anterior-posterior) direction [1]; and 2) a sagittal volume, consisting of 140 slices, slice thickness 1.0 mm, SENSE=2 in phase-encoding (anterior-posterior) direction, and SENSE=2 in slice-selective (left-right) direction, resulting in a total 2D-SENSE factor of 4. The increased slice thickness was chosen to compensate for signal-to-noise-losses due to larger degree of undersampling. Further imaging parameters, identical for both approaches, were: TR, 5.3 ms; TE, 2.6 ms; TFE factor, 25; acquisition window, 132 ms; in-plane resolution, 1x1 mm^2. Respiratory motion was taken into account using a prospective navigator in foot-head direction, placed on the right hemi-diaphragm, with an acceptance window of 5 mm [3].

Resulting data sets were reformatted along the left main (LM)/left anterior descending (LAD), the left circumflex (LCX), and the right coronary artery (RCA) using a three-point planscan tool. Data sets were exported to a PC, and vessel length, vessel sharpness, and vessel diameter were determined in the SoapBubble tool [4]. Signal-to-noise ratios (SNR) were determined in the ascending aorta. The two approaches were compared using a Wilcoxon matched-pairs signed-ranks test with a significance level of 5%.

Results: Imaging was successful in all subjects. The sagittal (SENSE=4) approach resulted in significantly smaller mean visible vessel length of the LCX (6.6 cm vs. 8.0 cm in the transverse (SENSE=2) approach; p=0.03). The other vessels investigated showed slightly, but not significantly reduced vessel length (LM/LAD, -8%, p=0.58; RCA, -2%, p=0.8). Mean vessel sharpness was slightly, but not significantly, reduced (LM/LAD, -6%, p=0.22; LCX, -5%, p=0.44; RCA, -6%, p=0.11), and was >0.39 for all vessels. Vessel diameter was virtually unchanged (±0.2 mm). SNR was non-significantly increased by 5% in the SENSE=4 approach. Mean acquisition time was significantly reduced by 52% (SENSE=4, 6:02±1:04 min (range, 5:10–8:17 min); SENSE=2, 12:28±2:54 min (range, 8:24–17:05 min); p=0.02), with a mean navigator efficiency of 54%.



SENSE=2 SENSE=4

***Figure 1:** Reformatted coronary MRA's showing the LM and LAD (top) and RCA and LCX (bottom) acquired with the two whole-heart approaches. Imaging time in this volunteer was 11:22 min (SENSE=2) and 5:40 min (SENSE=4).*

Conclusions: A coronary MRA approach has been shown that allows whole-heart coverage in little more than 6 minutes. Acquisition duration is thus virtually identical to that of a conventional targeted approach covering only a single vessel [5]. The thick volume is ideally suited for SENSE-acceleration in slice-selective direction, which allows the use of 2D-SENSE to further shorten acquisition time without severe penalty in SNR or image quality. A reduction in through-plane resolution might be responsible for a small decrease in vessel sharpness and visible vessel length, as well as a slight increase in SNR. Overall, both approaches provided similarly good image quality.

References: [1] OM Weber et al, MRM, in press. [2] JH Brittain et al, MRM 33, 689 (1995). [3] Y Wang et al, Radiology 198, 55 (1996). [4] A Etienne et al, MRM 48, 658 (2002). [5] WY Kim et al, NEJM 345, 1863 (2001).