An optimized coil setup for whole-heart coronary MRA using 2D-SENSE

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Introduction:
Recently, a “whole-heart” imaging protocol for coronary MRA has been suggested [1], which covers the entire heart with a large non-angulated 3D measurement volume. Scan time is reduced using sensitivity encoding (SENSE) [2] along one phase-encoding direction. In this work, accelerated “whole-heart” coronary imaging with SENSE in both phase-encoding directions (2D-SENSE) [3] was investigated. To reduce the spatially dependent noise amplification in SENSE, an optimal coil setup was derived. In-vivo feasibility of 2D-SENSE for “whole-heart” imaging is demonstrated on healthy subjects.

Methods:
In SENSE images, the SNR depends on a spatially varying function g(r) (g-factor), given by: $SNR(r)^{SENSE} = SNR^{full} / (g(r) * R^{1/2})$
(r=position vector, R=reduction factor, SNR^{full} =SNR without SENSE) [3]. Therefore, in an optimized coil setup, the g-factor on the heart should be as small as possible. For coil setup optimization, an array of 6 rectangular coil elements (R1) was arranged in 12 different geometric configurations. For comparison, a commercial cardiac-synergy coil was used. The measurements were performed on an elliptical phantom simulating the thorax. A low resolution SENSE reference scan (FOV=370x370mm^2, 20 slices, voxel-size: 7.7x7.7x8mm^3, TR=8ms; TE=1.6ms; flip angle=5°) was acquired for each coil setup. For evaluation of the phantom data, an ellipsoid of the size of the heart was positioned in the phantom images at the in-vivo location of the heart, and the mean g-factors inside were calculated (Figure 1c,f). This was used as a measure for the decrease of SNR expected on the heart in-vivo. The orientation of the measurement volume was varied (transversal/coronal) as well as the reduction factor (R=2.25, 3, 4) for 2D-SENSE.

The coil setup of the phantom measurement with the lowest g-factors was tested on three healthy subjects. A steady-state-free-precession sequence (TR=5.2ms, TE=2.6ms, flip angle=90°, 17 RF excitations/cardiac cycle) with real-time respiratory motion correction was used. A 3D volume with 90 coronal slices (slice thickness=1.5mm, reconstructed to 0.75mm, FOV=240x240mm^{2,} resolution=1x1mm^2) was acquired. All measurements were performed on a 1.5T Philips Intera (Philips Medical Systems, Best, The Netherlands).

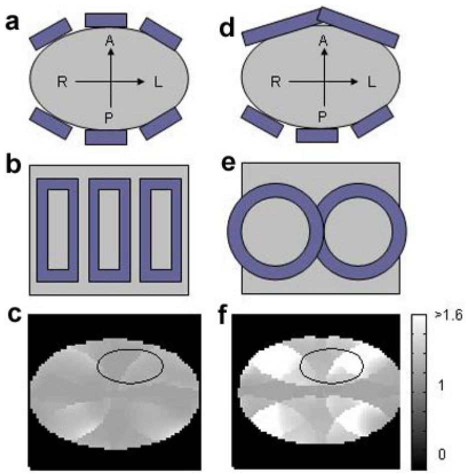

Figure 1: The g-maps of two different coil setups (left=6 R1 coils, right=cardiac-synergy-coil, R=4). The ellipse in the g-map indicates the position of the heart.

Results:
The calculations of the g-maps revealed that the standard cardiac-synergy coil (Figure. 1d,e,f) is not optimally suited for coronary MRA at SENSE factors greater than two. Instead, a symmetric array of 3 R1 coils on the front- and the backside with the two phase encoding directions along the right-left (RL) and anterior-posterior (AP) directions performed best (Figure. 1a,b,c). Using the optimized coil setup, the g-factor was 5-120% lower when compared to the cardiac-synergy coil, depending on the reduction factor.
An in-vivo measurement using this optimized coil setup is shown in Figure 2. In particular, the left anterior descending coronary artery (LAD) can be displayed over a long segment. Although a reduction factor of 2.25 was used the noise in the image is relatively small.

Conclusions:
Using an optimized coil setup, lower g factors are achieved when compared to the conventionally used cardiac-synergy coil array. This enables “whole-heart” coronary MRA with 2D-SENSE at acceleration factors greater than two.

References:
[1]Weber O.M. et al., JCMR **5**: 23-24 (2003)
[2]Pruessmann K.P. et al., MRM **42**:952-62 (1999)
[3]Weiger M, et al., MAGMA **14**: 10-19 (2002)

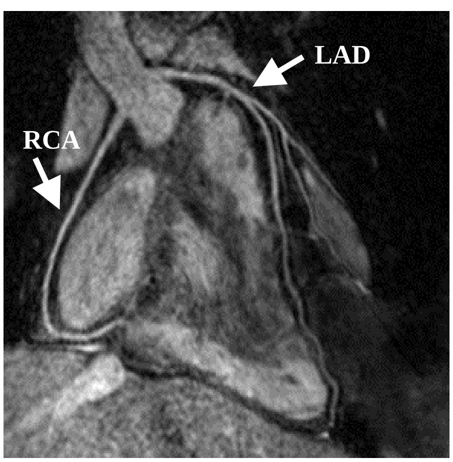

Figure 2: Simultaneous visualization of the right coronary artery (RCA) and the LAD. The image was acquired with the coil setup shown in Figure 1a,b and 2D-SENSE (R=2.25).

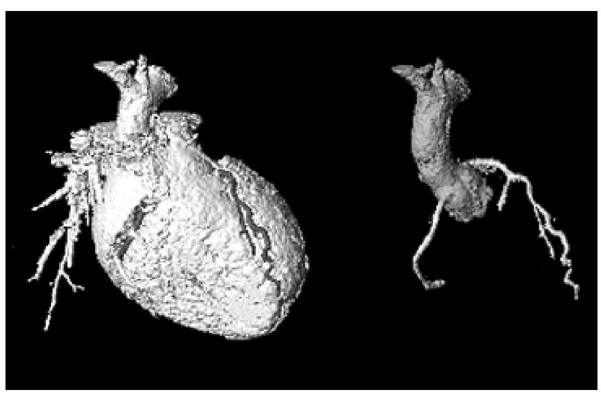

Figure 3: 3D surface rendering of the heart, showing the coronary arteries reconstructed from a “whole-heart” scan with 2D-SENSE