# Comprehensive coronary artery imaging at 7.0 T: Proof of feasibility

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**Introduction** Clinical coronary MR imaging demands a compromise between acquisiton speed, spatial resolution and adequate signal-to-noise ratio (SNR). Migration to higher field strengths such as 3T and 7T has the potential to improve this trade-off, but image quality can be suboptimal due to $B_0$ and $B_1$ inhomogeneity. Prior work on coronary imaging at 7T [1-3] has reported successful imaging of the right coronary artery (RCA) and the left anterior descending artery (LAD). However, imaging of the left circumflex artery (LCX) has, to our knowledge, never been presented. The objective of this work is to demonstrate the feasibility of comprehensive coronary artery MR imaging at 7T (including all three major coronary arteries) with a study on 9 healthy volunteer subjects. Imaging is performed using a novel 8-channel transmit receive array with modified dipole antennas [4].

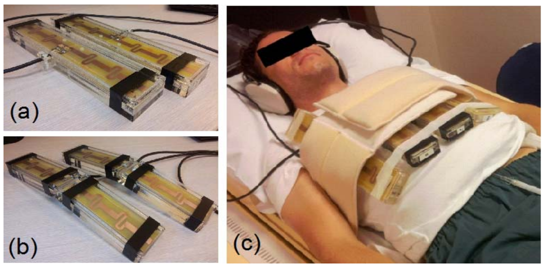


*Figure 1: Cardiac imaging at 7 Tesla with coil array of fractionated dipole antennas a) regular elements b) bent elements for central placement on the chest c) imaging setup with 8 elements*

**Methods** Images were acquired on a 7T Philips Achieva multi-transmit system with 8 x 1 kW RF amplifiers. A custom built transmit/receive coil array was used consisting of 8 fractionated dipole antennas [4] (figure 1). Two anterior elements were adapted to the chest curvature (fig. 1b). To establish safe RF transmit power usage, energy deposition by the elements in human tissue was simulated using the FDTD package SEMCAD X (Speag, Zurich, CH). Simulation results showed that the average power should be limited to maximum 8 x 3.3 W to avoid tissue heating (10g averaged local SAR level remains below 20 W/kg for all phase settings). Potential variation between imaging subjects and simulated model was accounted for by an additional limitation of the average power to 8 x 1.6 W. Note that these limits are extremely conservative as they rule out any sources of accidental violation of the limits by worst-case phase settings or subject anatomy. ECG pads and a respiratory belt consistently provided stable triggering signals for all imaging subjects (6 males, 3 females; age: 20-33 years, IRB approval). $B_1$ phase shimming was performed over the entire heart (3D shim) after which a 10 slice planning sequence was acquired consisting of 10 cine acquisitions during breath-holds. This dataset was used to plan each coronary artery scan with a 3-point plan scan procedure. All coronary artery scans were 3D TFE scans with 1.2 x 1.2 x 1.5 $mm^3$ resolution, 25º flip angle, TFE factor of 20, TR/TE = 4.5/1.48 ms and optimal signal combination (unity SENSE factor). The RCA was scanned with 12 slices in 4m11s nominal scan time using the same $B_1$ shim settings as for the planning scan. For the LAD and the LCX, $B_1$ shim settings were optimized for the corresponding imaging orientation. These latter arteries were scanned with 20 slices in a nominal scan time of 5m55s. Respiratory gating efficiency varied between 40 and 60%.

**Results** Parts of the imaging results are presented in figure 2. Imaging of the LCX and LAD succeeded for 6/9 and 7/9 subjects. Failures were caused by planning difficulties and/or non-dominant vessels (LCX). The RCA is easier to depict. However, for two subjects insufficient time remained for imaging the RCA due to difficulties in imaging the LCX/LAD and/or technical problems. For all of the remaining seven subjects, the RCA was successfully depicted. Overall, imaging quality is generally good, but is dependent on some issues including $B_1$ shimming performance, impedance matching of the elements, and dominance of the vessels. Figure 3 shows that there is sufficient SNR such that the LCX can be imaged with very high resolution (fewer slices).

**Conclusion** These results provide a promising showcase that coronary artery imaging is feasible at 7 Tesla.

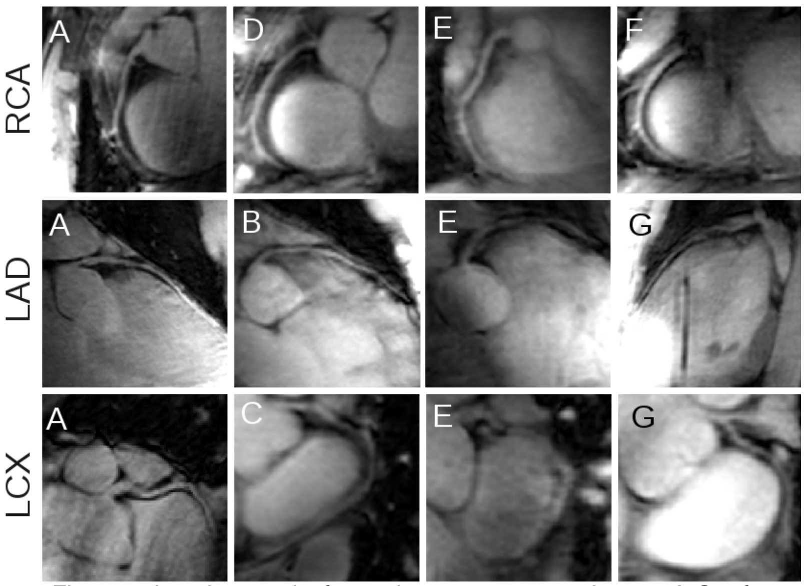


*Figure 2: Imaging results for each coronary artery. Letters A-G refer to 7 (out of 9) imaging subjects.*

References: [1] Metzger et al. ISMRM 2011 [2] Hezel et al. ISMRM 2013 [3] Van Elderen et al. Radiology 2010 [4] Raaijmakers et al. ISMRM 2013

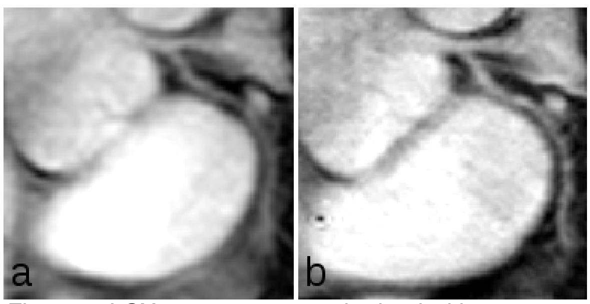


*Figure 3: LCX coronary artery obtained with a) 1.2 x 1.2 x 1.5 $mm^3$, (recon 0.8 mm) 20 slices, 5m55 b) 0.8 x 0.8 x 1 $mm^3$ (recon 0.8 mm) 10 slices 4m13s*