7 T cardiac imaging with array of radiative antennas compared to loop coil array

Alexander J.E. Raaijmakers[1], Maarten J. Versluis[2], Sebastian A. Aussenhofer[2], Hamza El Aidi[1], Peter Luijten[1], Tim Leiner[1], Cornelis A.T. van den Berg[1], and Andrew Webb[2]

[1]Imaging Division, UMC Utrecht, Utrecht, Netherlands, [2]J.C. Gorter Institute, LUMC, Leiden, Netherlands

Introduction Body imaging at 7 Tesla faces considerable challenges in achieving the full SNR improvement associated with higher field strengths. Due to the relatively weak attenuation of the B1 signals by the low density lungs, the heart is an organ inside the body that is likely to show good image quality at 7 Tesla, in comparison to targets in the abdomen. Good quality images have been demonstrated by a couple of pioneering institutes [1-3]. The majority of these institutes have used either stripline or loop coils. Recently an entirely different coil array element was introduced: the single-side adapted dipole antenna, or radiative antenna [4]. In this work, we compare the imaging performance of cardiac imaging with an array of large loop coils to that with an array of radiative antennas.

Figure 1: Positioning of array elements on volunteer
a) radiative antennas b) loop coils

Materials and methods Six large loop coils (13.5 x 17.8 cm) were constructed. Each element was tuned and matched to 50 Ohm. A 3 cm thick foam layer on each element guaranteed sufficient spacing of the elements to the volunteer. The six elements were positioned around the torso of the volunteer as indicated in figure 1. The eight single-side adapted dipole antennas were equivalent to a recent publication on prostate imaging [4]. The two outer upper elements consisted of the ceramic substrate K90, with a permittivity of 90 and dimensions 11.7 x 5.8 x 3.0 cm^3. Both coil arrays were simulated with the human model Duke using the FDTD package SEMCAD X (SPEAG, Schmid & Partner Engineering, Zurich, Switzerland) to evaluate the B_1^-, B_1^+ and local SAR distributions (averaged over 10g). After B1 phase shimming, a PPU triggered cine MR of the cardiac cycle was recorded by a 2D FFE TFE sequence with TR/TE of 6.0/2.3 ms, 1.3 x 1.3 mm^2 resolution, 8 mm slice thickness and low flip angle (6, 8 or 12°) to avoid interference of B1 with the PPU signal. The right coronary artery was imaged by a 2D segmented gradient echo (TR/TE = 4.3/1.8 ms, 0.8 x 0.8 mm^2 resolution, 2 mm slice thickness and a 15° flip angle).

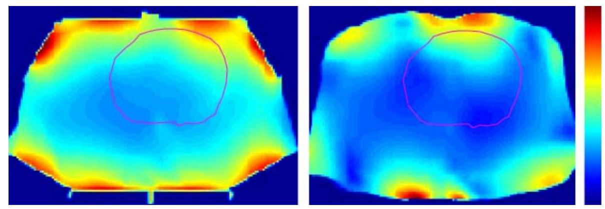

Figure 2: Simulated coil array sensitivity
a) radiative antenna array b) loop coil array

Figure 3: Transverse image of thorax and heart with radiative antenna array.

Results Simulation results show that the average sensitivity in the heart (sum of magnitude of B_1^- distributions, normalized to power) is twice as high for the radiative antenna array, compared to the loop coil array (figure 2). Also, the array of 8 radiative antennas reaches 45% more B_1^+ than the 6 loop elements, with equal total input power. However, SAR levels for the radiative antenna array were much higher (14.3 W/kg vs 3.72 W/kg), mostly because the loops are able to spread the power over a larger surface area.
All measurements were performed on a Philips Achieva 7 Tesla system. During the measurements, we experienced that phase shimming with the array of radiative antennas was much easier than phase shimming with the array of loop coils. A possible explanation is that the phase patterns of the radiative array are more regular, causing fewer signal voids in the image (figure 3). With both arrays, a short-axis view of the heart was imaged (figure 4). Both images show good heart coverage. But shimming for the loop coil array took more iterations. The SNR of the 8 element radiative array was visibly higher than the SNR of the 6 element loop coil array. The right coronary artery could be imaged well, as indicated in figure 5.

Conclusions Both simulations and measurements show that the radiative antennas have better B_1 penetration than the large loop coils. Additionally, the radiative antennas have more regular B_1^+ fields that are easier to shim with. However, the loop coil arrangement is currently much more comfortable and has much lower SAR levels. Good quality images of the right coronary artery were obtained with the radiative antenna array. The coverage of the heart by this array would in principle allow the imaging of the left coronary artery as well, which will be the next step to pursue.

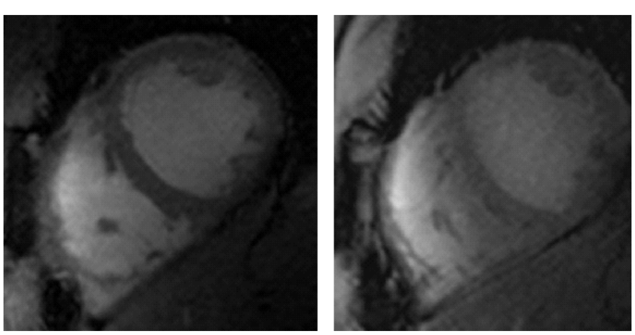

Figure 4: Cine MR of short axis view
a) radiative antenna array b) loop coil array

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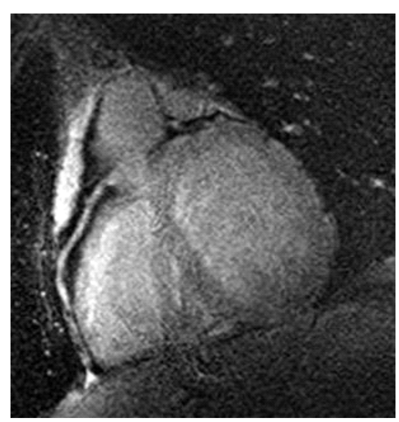

Figure 5: Right coronary artery image obtained with the radiative antenna array