Improvements in Cardiac MRI at 3T using High Permittivity Materials

Wyger Brink[1] and Andrew Webb[1]
[1]*Radiology, Leiden University Medical Center, Leiden, Netherlands, Zuid-Holland, Netherlands*

Target audience: Clinicians and researchers performing cardiac imaging at 3T.

Purpose: To improve image quality and reduce RF power in cardiac imaging at 3T using high permittivity pads.

Methods: Two high permittivity pads were numerically designed using an electromagnetics simulation package (xFDTD, Remcom inc., State College, PA, USA) and implemented using a very dense aqueous suspension of barium titanate (ε_r~300). The pads had a size of 20-by-20 cm and the thickness was 1.5 cm for the anterior and 1.0 cm for the posterior pad.

Eleven healthy volunteers (5 male, 6 female, BMI 23.5 ± 4.7 (mean ± standard deviation)) were scanned on a Philips Achieva 3T TX equipped with dual-transmit technology. Radiofrequency (RF) transmission was performed with the body coil driven in either quadrature or RF shimmed mode, with and without the high permittivity pads in place. Signal reception was performed using a commercial 6-channel coil array. All image acquisitions were cardiac-gated using a pulse oximetry sensor. Written informed consent was obtained in all volunteers.

B_1 maps were acquired in the transverse and sagittal plane using a saturated double-angle method (SDAM) with a nominal flip angle of 40 degrees and a resolution of 5 x 5 x 10 mm^3 [1]. The B_1 maps were converted into transmit efficiency maps by dividing by the square root of the required RF power. The mean transmit efficiency and relative standard deviation were determined in a manually drawn region of interest (ROI).

Functional cardiac cine images were acquired using a balanced steady state free precession (bSSFP) sequence planned along the long and short axis of the heart. Sequence parameters were: TR = 'shortest' (typically 2.5 to 3.0 ms); flip angle = 40°; resolution 2 x 1.6 x 8 mm^3; sensitivity encoding (SENSE) factor = 2. The average RF power required to perform the cine is recorded for comparison. The contrast-to-noise ratio (CNR) for the bSSFP images was measured between the septum and blood pool. Statistical significance was determined using a double sided paired t-test. Additionally, the effect of the dielectric pads on black blood and right coronary images was assessed.

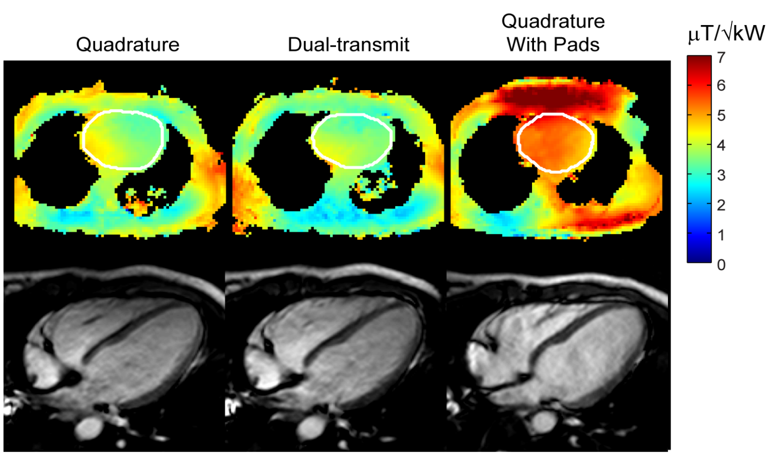

Figure 1. Measured transmit efficiency maps (upper) and cine images (lower) acquired in the transverse plane in three transmit configurations. The ROI for evaluation of the transmit efficiency maps is indicated in white.

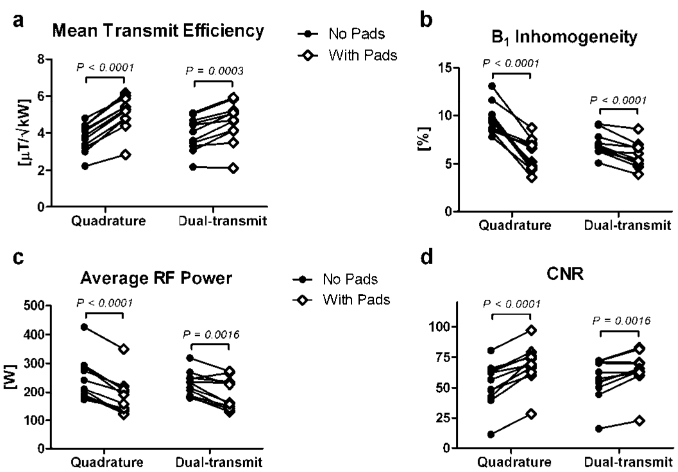

Figure 2. Paired plots of the mean transmit efficiency (a), B_1 homogeneity (b), average RF power (c) and CNR (d) showing significant improvements.

Results: Figure 1 shows the transmit efficiency and cine images in the long-axis view which indicates the substantial improvements when introducing the dielectric pads. The dielectric pads increased the mean transmit efficiency by as much as 40%. The cine images show superior image quality and contrast along the septum when compared to dual-transmit [2]. Figure 2 shows the paired statistical analysis indicating the significance of the improvements. Smaller improvements were observed in the quality of the black blood and right coronary images with the pads in place.

Discussion: Previous work has shown that high permittivity pads designed for improving global homogeneity in abdominal imaging showed a similar improvement as compared to dual-transmit RF shimming [3]. This current study shows that high permittivity pads significantly improve image quality and transmit efficiency, and are much more effective for local RF shimming compared to dual-transmit RF shimming. The reduction in average power means that, for example, shorter TR values can be used while remaining within SAR limits, thus improving image quality yet further.

Conclusion: High permittivity pads are shown to improve the transmit efficiency, B_1 homogeneity and CNR in bSSFP imaging significantly, resolving RF related artifacts commonly encountered in functional cardiac imaging at 3T. The proposed solution is shown to outperform dual-transmit RF shimming.

References: 1. Cunningham et al., *MRM 2006*, 55:1326–1333; 2. Mueller et al., *Radiology 2012*, 263:77–85; 3. de Heer et al., *MRM 2012*, 68:1317–1324.