4CH TX/RX SURFACE COIL FOR 7T: DESIGN, OPTIMIZATION AND APPLICATION FOR CARDIAC FUNCTION IMAGING

M. A. Dieringer[1,2], W. Renz[1,3], T. Lindel[1,4], F. Seifert[1,4], T. Frauenrath[1], H. Waiczies[1,4], F. von Knobelsdorff-Brenkhoff[5], D. Santoro[1], W. Hoffmann[4], B. Ittermann[1,4], J. Schulz-Menger[2,5], and T. Niendorf[1,2]

[1]Berlin Ultrahigh Field Facility, Max-Delbrueck-Center for Molecular Medicine, Berlin, Germany, [2]Experimental and Clinical Research Center (ECRC), Charité Campus Buch, Humboldt-University, Berlin, Germany, [3]Siemens Healthcare, Erlangen, Germany, [4]Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany, [5]CMR-Unit Charité Campus Buch, Berlin, Germany

Introduction

Practical impediments of ultra high field cardiovascular MR (CVMR) can be catalogued in exacerbated magnetic field and radio frequency (RF) inhomogeneities, susceptibility and off-resonance effects, conductive and dielectric effects in tissue, and RF power deposition constraints, which all bear the potential to spoil the benefit of CVMR at 7T. Therefore, a strategy employing RF transmit/receive coil arrays dedicated for CVMR in conjunction with improved RF uniformity (B1 shimming) is essential. For this purpose, a four element cardiac transceive surface coil array was developed. Its clinical efficiency for ultrahigh field CVMR is demonstrated in rapid cardiac cine acquisitions.

Methods

A 4-element cardiac transmit/receive coil array was constructed on two modestly curved lightweight formers to conform to an average chest and back providing a clinically acceptable coverage of the heart. Two rectangular loops were mounted on the anterior former (Figure 1) and two rectangular loops on the posterior former. Coil decoupling for neighboring loops (13cmx20cm each) was achieved by a common conductor for the two loops and a decoupling capacitor. The subject's body decoupled the anterior and posterior part of the coil. Cables were elevated by a few centimeters to minimize cable interactions.

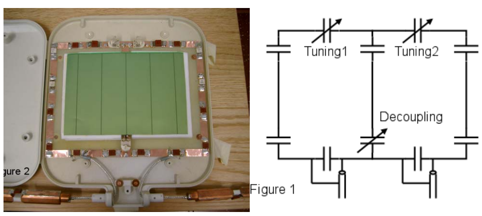

Fig.1 The 4 channel surface coil interior together with the circuit diagram. The center conductor is hidden by the RF screen.

The prototype 4 element cardiac surface coil array was connected to a 7T whole body MR system (Magnetom, Siemens Medical Solutions, Erlangen, Germany) via an interface box containing T/R switches, preamplifiers and a 1:4 RF power splitter. B_1^+ shimming was accomplished by phase optimization. To achieve high flip angles at 7T to afford blood/myocardium contrast while not exceeding RF power deposition limits, the coil design underwent SAR (specific absorption rate) simulations. For volunteer studies, a retrospectively triggered 2D CINE FLASH sequence (breathhold; TE=2.7ms; TR=5.4ms; voxel size = (1.4x1.8x4) mm³; temporal resolution = 49ms; total scan time: ~20s) was applied.

Results

Decoupling between adjacent loops was measured to be >18dB (with patient load) while decoupling between opposite loops was found to be >20dB. The coil provided an unloaded Q = 70 and a loaded Q = 10.

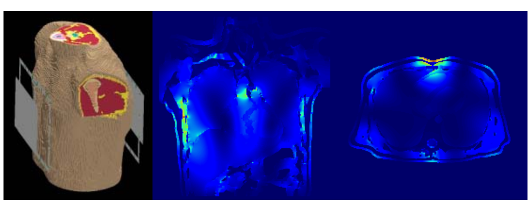

Fig.2 Simulation setup with a torso model (left). Results of the SAR simulation in a coronal slice (center) and a transversal slice (right). The RF power deposition is scaled from blue (low SAR values) to red (maximum SAR).

The averaged partial body RF exposure was limited to 1,4W/kg in the measurements and thus within the regulatory limits provided by the IEC (4 W/kg, 1st level). When driving the coil with 30W, the local peak SAR for 10g of tissue calculated from the SAR simulations did not exceed 20W/kg, which is in compliance with the IEC (60601-2-33, Ed.3, Status FDIS).

In vivo results are illustrated in Fig. 3. The red circles indicate the signal loss due to B_1 non-uniformities. B_1^+ shimmed images derived from short axis and long axis views of the heart provided clinically acceptable signal homogeneity with an excellent blood myocardium contrast. Subtle anatomic structures, such as pericardium, mitral and tricuspid valves and their apparatus, papillary muscles, and trabecles are accurately delineated.

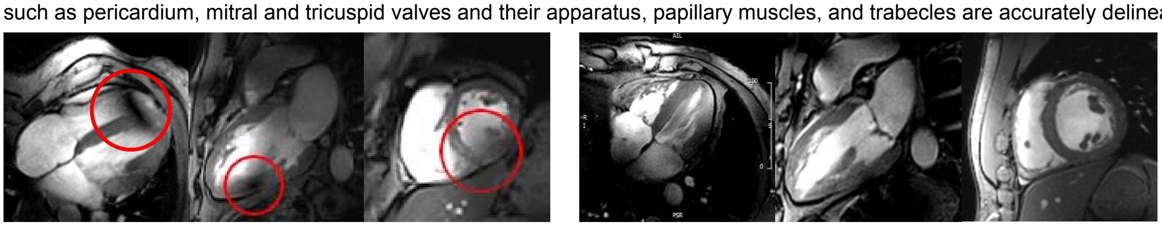

Fig.3 Triggered 2D CINE FLASH images acquired in the late diastole without B_1^+ shimming (left) vs. with B_1^+ shimming (right). Signal homogeneity and tissue contrast is enhanced in B_1^+ shimmed acquisitions.

Discussion and Conclusions

The four-element cardiac transceiver array was found to meet the demands of CVMR at 7T in terms of B_1-uniformity and depth penetration as well as coverage of the whole heart. The array offers excellent patient comfort and ease of use due to its lightweight design. A broader clinical study is anticipated to compare the results obtained for left ventricular function assessment at 7T with 1.5T data sets.