An Expandable Catheter Loop Coil for Intravascular MRI in Larger Blood Vessels

A-K. Homagk[1], R. Umathum[1], M. Korn[1], M-A. Weber[2], P. Hallscheidt[2], W. Semmler[1], and M. Bock[1]

[1]Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany, [2]Diagnostic and Interventional Radiology, University Hospital, Heidelberg, Germany

Introduction

Intra-arterial MRI has recently been demonstrated in several arterial blood vessels using catheter coils with different coil configurations [1, 2]. In larger arteries such as the aorta high-resolution imaging can be difficult as imaging with solenoid catheter coils suffers from motion artifacts, while balloon-mounted catheter designs block or decrease the arterial blood flow. The present study proposes a catheter system with an expandable coil which combines the advantages of a very small insertion diameter, a longitudinal extent of nearly 2 cm for multi-slice imaging, and an increased SNR and penetration depth due to the expanded coil surface.

Materials and Methods

The imaging catheter consists of a 9 F sheath tube which contains an expandable single-loop coil directly attached to a fully insulated micro-coaxial cable (Figure 1). The coaxial cable (∅: 300 µm, length: 120 cm) conducts the MR signal from the tip to the base of the catheter. The coil carrier was made of 25 µm thick Polyimid with a 17 µm copper coating that was etched off around the coil mask to yield the shape of the coil. The expanded coil is 18 mm in length and 7 mm in width. It is coated with Tecoflex® to obtain biocompatiblity.

All measurements were conducted on a clinical 1.5 Tesla whole body MR system (Siemens Magnetom Symphony, Erlangen, Germany). The in vivo performance of the catheter was tested in two healthy anesthetized pigs (body weight: 54 and 52 kg). After insertion through a 9 F sheath in the femoral artery, the catheter was advanced into the abdominal aorta. A real-time imaging trueFISP sequence was then used to demonstrate the coil's signal characteristics during expansion. Image data was recorded with the spine array coils, a CP body array extender coil and the catheter coil. For high-resolution vessel wall imaging with the expanded coil, a pulse sequence was implemented as a combination of a 2D flow-compensated FLASH sequence with the acquisition of projection data (Figure 2). After the acquisition of each k-space line, a non-selective excitation followed by the acquisition of a projection data set is applied for each spatial axis to determine the position of the imaging coil. To suppress background signal from static tissue, additional dephaser gradients are applied. 40 data sets were acquired using the following imaging parameters: TR = 26 ms, TE = 9.8 ms, FOV = 29×29 mm², matrix = 192×192, 150 µm resolution, slice thickness = 2 mm, $\alpha = 15°$. The projection data were analyzed with an auto-correlation algorithm to determine the catheter position with sub-pixel precision. For motion compensation, a range of positions was defined which were accepted as input for the subsequent image calculation [3].

Results and Discussion

The images acquired during the expansion of the catheter coil revealed the expected higher signal intensity once the coil was expanded (Figure 3). By the use of the projection data, catheter shifts of $\Delta x/\Delta y/\Delta z$ = 1.3 mm / 8.3 mm / 7.4 mm were detected. Due to the extent of the coil in *y* (L-R) and *z* (H-F) direction, the calculated shifts were bigger than the shift in *x* (A-P) direction. The best image quality was achieved when the acceptance range for the image input data was chosen as one quarter of the shift amplitude, i.e. $\Delta x/\Delta y/\Delta z$ = 0.3 mm / 2.0 mm / 1.8 mm. Figure 4 shows a comparison of an uncorrected and a motion-corrected image, which show different layers of the aortic wall. The performed experiments revealed the capability of this catheter design for tracking and high-resolution imaging. The use of projection data for motion correction leads to a significant improvement in image quality compared to uncorrected images. The vessel wall conspicuity might further be improved by the use of a coil with a larger surface area.

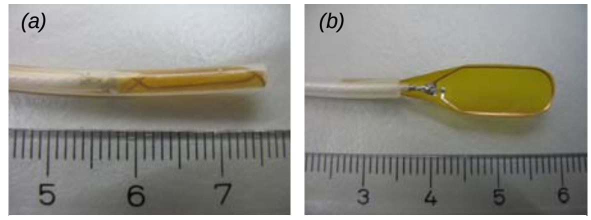

Fig 1. Expandable catheter coil with (a) the coil rolled up in the sheath and (b) the expanded coil after retraction of the sheath.

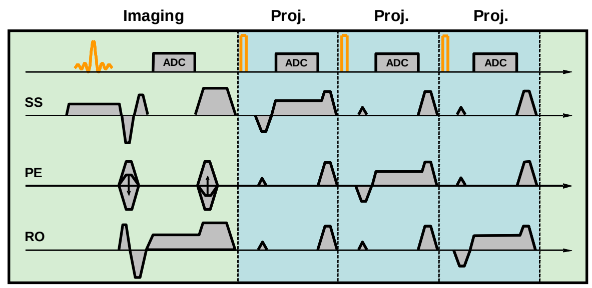

Fig 2. Schematic of the 2D FLASH projection pulse sequence with projections in all three spatial directions.

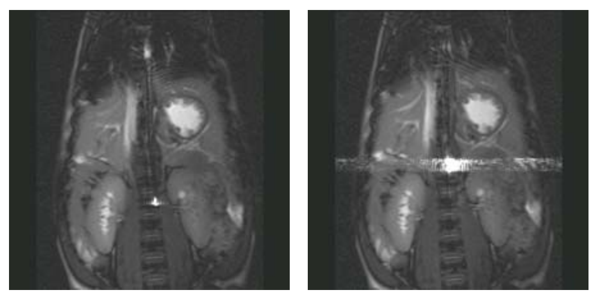

Fig 3. Coil signal during the expanding process: (a) Coil rolled up. (b) Coil expanded.

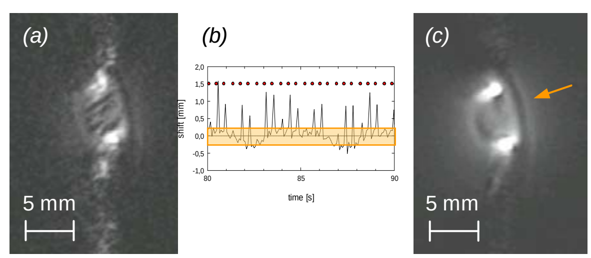

Fig 4. 150 µm resolution images of the aortic wall: (a) Uncorrected image. (b) Catheter shift with acquisition window (orange) and ECG trigger (red dots). (c) Motion-corrected image, different layers of aortic wall can be seen (arrow).

References

[1] Hillenbrand CM et al.: Active Device Tracking and High-Resolution Intravascular MRI Using a Novel Catheter-Based, Opposed-Solenoid Phased Array Coil, Magn Reson Med 2006; 23:135-144.

[2] Quick HH et al.: Single-Loop Coil Concepts for Intravascular Magnetic Resonance Imaging, Magn Reson Med 1999; 41:751-758.

[3] Homagk AK et al.: Motion-Corrected Intravascular MRI with an Active Tracking Catheter, 16th ISMRM 2008, 1202.