Development of a catheter-mounted cardiac RF coil for temperature imaging in atrial fibrillation treatment

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Purpose

The potential of MRI to allow 3D soft tissue visualization makes MRI-guided RF ablation a promising procedure for atrial fibrillation (AF) treatment **[1]**. With appropriate real time pulse sequences that achieve sufficient speed, resolution, and signal-to-noise ratio (SNR), the real-time visualization and monitoring of lesion formation using MR thermometry could improve outcomes of the procedure.

Previously, the acquisition of limited field of view (FOV) temperature images with high sensitivity within a beating heart were made possible with the use of a local RF cardiac coil placed on the heart **[2]**. However to be used clinically, the local coil has to be inserted in the heart with minimum invasiveness, mounted on a catheter, and made foldable. For this reason, the development of an expandable catheter-mounted local RF cardiac coil was evaluated in this study.

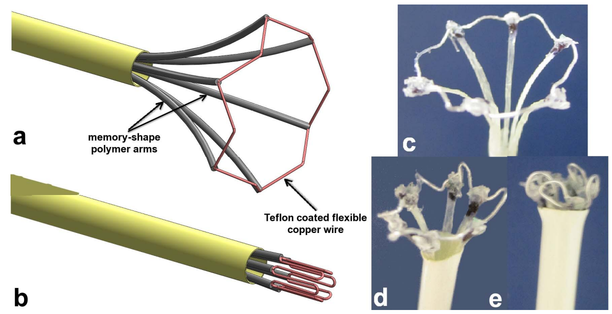

Figure 1: Coil loop expansion. (a) Schematic of the loop expanded out of the sheath; (b) The loop folded going back into the sheath; Picture of the coil loop: (c) corresponding to (a); (d) being folded back in the sheath; (e) corresponding to (b).

Methods

Several methods have been considered for catheter-mounted coil expansion. One promising technique used thin solid elastic fiberglass filaments formed with a predetermined curvature on one end to allow the coil loop expansion to the desired size. This design has the advantage of minimal reduction of blood flow. In our work a small (2-cm diameter) loop, made of a 38 AWG copper wire, was fixed on top of the cone formed by 6 pre-shaped filament arms equally spaced around the loop to provide consistent folding and unfolding (**Figure 1**). Both ends of the inductive loop were soldered to a microcoaxial cable (Axon Cable SAS, Montmirail, France) 2 cm down the filaments and sealed within a 9 Fr sheath to protect the electrical connections from being wet. The microcoaxial cable allows the connection of the loop to the receiver circuit board at the end of the 9 Fr sheath (**Figure 2**). For insertion into the outer catheter sheath, the wire folded based on preset bends in the loop as shown in **Figure 1**. No passive circuit component was placed in the loop or on the microcoaxial cable not only due to space contrains but also to avoid loop unproper folding and image phase distorsions near the coil. For expansion, the support arms were pushed out of the catheter sheath until the loop was fully extended.

The initial prototype catheter-mounted expandable coil was designed and constructed with the constraint that the design must fit within an 11Fr (3.7 mm OD) catheter sheath, which is the largest diameter sheath to be placed in the animal (pigs) for vascular access.

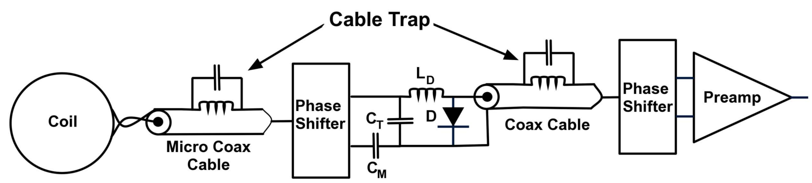

Figure 2: Coil circuit diagram. The tuning, matching and decoupling circuit to make the coil receive-only were positioned after the 24-cm long (~ λ/10) microcoaxial cable running down the sheath. A cable trap to minimize common-mode currents on the cable **[3]**, and a phase shifter to maintain λ/2 phase shift between the coil and the tuning and matching circuit were placed on the receiver circuit board. An RG-316 coaxial cable connected the receive-only circuit board to the low input impedance preamplifier **[4]**.

MRI scans were performed on a 3T TIM Trio scanner (Siemens Healthcare, Erlangen, Germany) using a Gradient Echo (GRE) pulse sequence with TR= 10.1 ms, TE= 6 ms, pixel size 2 x 2 mm^2, 2-mm slice, flip angle= 15˚. The FOV was 192 x 192 mm^2.

Results and Discussion

The local coil was tuned at 123.23 MHz (3T). The maximum return loss was -20 dB when the coil was loaded with a saline phantom. The coil achieves a maximum active detuning of -20 dB to properly decouple the local coil during RF excitation. The quality factor (Q) of the loaded coil was 10 ± 3. The images acquired using the prototype expandable are showed in **Figure 3**.

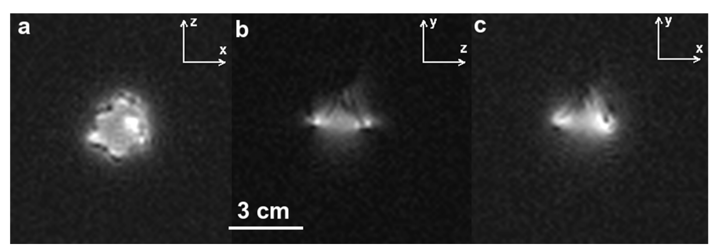

Figure 3: Zoomed-in MR magnitude images acquired using the prototype expandable cardiac local coil. (a) coronal view; (b) sagital view; (c) axial view. The coil was positioned in an homogeneous of a saline phantom with its axis perpendicular to the patient table (scanner y direction). B_0 was in the z direction.

Conclusions

The prototype of an expandable catheter-mounted local cardiac coil was successfully constructed and used to acquire images at 3T in a saline phantom. The imaging results showed that the SNR profile and FOV coverage (3 x 3 cm^2 in the coronal direction) are adequate for MR thermometry measurements. Ongoing work is now focused on 1) improving mechanical stability and increasing safety of such a coil, 2) testing the coil for MR thermometry and assessing its accuracy, and 3) optimizing such a coil toward *in vivo* and clinical use.

References **[1]** Vergara, G.R., et al., Heart Rythm, 2011. **[2]** Volland, N.A., et al., MRM, 2012. **(In Press)**. **[3]**. Peterson, D.M., et al., CMRb, 2003. **[4]** Reykowski, A., MRM, 1995.

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