Catheter-mounted expandable loop (CAMEL) balloon RF coil for high-resolution intracardiac MR imaging

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Target Audience: hardware engineers, implantable RF coil designer

Purpose: In catheter-based cardiac interventional applications, obtaining high sensitivity images of a localized treatment volume would often be more important than low sensitivity images of the full anatomy. However, currently available external RF cardiac coils limit the image acquisition to large field-of-view (FOV) imaging covering the full anatomy to prevent aliasing. To overcome such sensitivity limitations, intracardiac RF coils positioned within the cardiac chambers would be of primary consideration **[1]**. High sensitivity imaging results acquired using a local RF cardiac coil placed on the external surface of a beating heart and using a limited FOV have been shown previsouly **[2]**. Our first steps towards the development of a clinically useful intracardiac coil were the catheter-mounted expandable loop (CAMEL) coil (umbrella version) **[3].** In this study, we investigated an expanding balloon version of such a CAMEL coil.

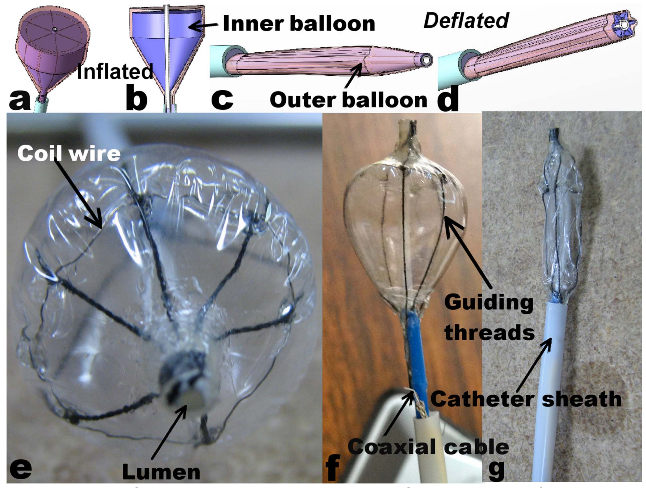

Figure 1: Coil loop expansion. (a) Schematic of the loop expanded out of the sheath; (b) Vertical cross section of the balloon catheter; (c) Schematic of the loop folded and balloon expanded out of the sheath; (d) Horizontal cross section of the loop folded and balloon expanded out of the sheath. Picture of the coil loop: (e) front view; (f) lateral view of the prototype corresponding to (a); (g) lateral view of the prototype corresponding to (c).

Methods: The balloon design was investigated because of its easy folding/expanding scheme and the consistency of the expansion mechanism **[4]**. A 38 AWG copper wire coil loop was placed around the circular base of a conical balloon (**Figure 1a**). Six threads equally spaced and fixed at the bottom and the top of the balloon anchored the loop on the balloon to allow its complete expansion. The loop was sandwiched between an inner and outer balloon to protect the coil from fluids. Saline was used to inflate the inner balloon and expand the coil to reduce the susceptibility mismatch between the inner balloon volume and phantom solution, especially on the phase images. Since the saline MR signal within the inner balloon was going to have a bright signal and no contrast with the phantom saline, MnCl doped saline was used to inflate the balloon using 5 mMol of MnCl solution to null the balloon content signal.

For insertion into the outer catheter sheath, the balloon was deflated. To keep the folded balloon as compact as possible, the balloon ends were mounted on two different concentric sheaths to allow a longitudinal extension and a thinner fold as shown in **Figure 1c**. The loop was connected to the receiver circuit board at the end of the 10 Fr sheath as previously described **[3]**.

The initial CAMEL coil balloon prototype was designed and constructed with the constraint that the design must fit within a 12Fr (4 mm OD) catheter sheath. 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 1 x 1 mm^2, 3-mm slice, flip angle= 15˚. The FOV was 192 x 192 mm^2.

Results and Discussion: The balloon CAMEL coil was tuned at 123.23 MHz (3T). The maximum return loss was -20 dB when the coil was immersed in 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 upon repeated folds and expansions was 34.8 ± 0.9 with air inflation and 39 ± 0.7 with liquid inflation (n>5). The images acquired using the prototype balloon expandable coil are shown in **Figure 2**. The SNR within the sensitive volume of the coil was determined at 539 (±9%), over 20 times the SNR of the external coils currently commercially available.

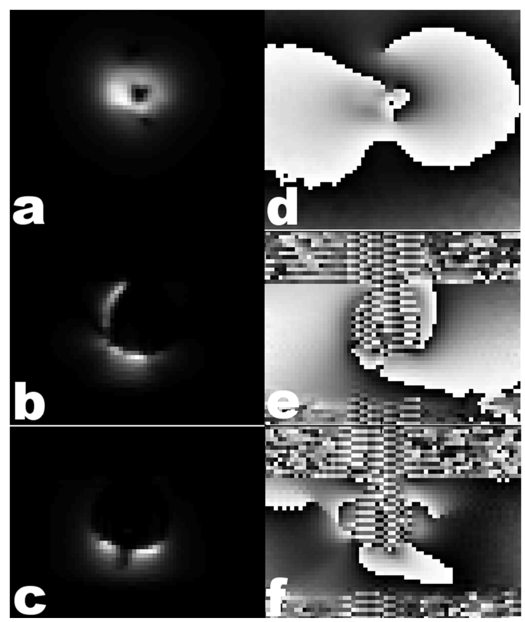

Figure 2: Zoomed-in MR images acquired using The balloon CAMEL coil. Magnitude views: (a) coronal; (b) sagittal; (c) axial. Phase: (d) coronal; (e) sagittal; (f) axial, The coil was positioned in a homogeneous saline phantom with its axis in the scanner y direction.

Conclusions: The balloon prototype of a CAMEL 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 high-resolution cardiac measurements. Ongoing work is now focused on 1) improving mechanical stability and increasing safety of such a coil, and 2) optimizing such a coil toward *in vivo* and clinical use.

References: **[1]** Schmidt, E. et al., US patent Application 13/509,719. **[2]** Volland, N.A., et al., MRM, 2013. **[3]** Volland, N.A., et al. ISMRM 2013. **[4]** Volland, N.A., et al. US Patent Application 61/887,611 (provisional).

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