In vivo limited FOV MR thermometry using a local cardiac RF coil in atrial fibrillation treatment

Nelly A. Volland[1,2], Eugene G. Kholmovski[1,2], J. Rock Hadley[1], and Dennis L. Parker[1,2]
[1]*UCAIR/Radiology, University of Utah, Salt Lake City, Utah, United States,* [2]*CARMA, University of Utah, Salt Lake City, Utah, United States*

Introduction

Atrial fibrillation (AF) is the most common cardiac arrhythmia encountered in clinical practice. MRI-guidance in the treatment of AF is a developing procedure that has shown great promises to improve treatment outcomes [1]. Applying MR thermometry [2] during an MR-guided RF ablation procedure could allow the visualization of lesions as they form. To be used in such procedures, MR thermometry within a beating heart must be acquired with high spatial and temporal resolution.

One way to satisfy these requirements would be to use a local RF cardiac coil that allows the acquisition of limited field of view (FOV) MR lesion or temperature images with high sensitivity. The feasibility of developing and using such a coil *in vivo* was investigated in this study.

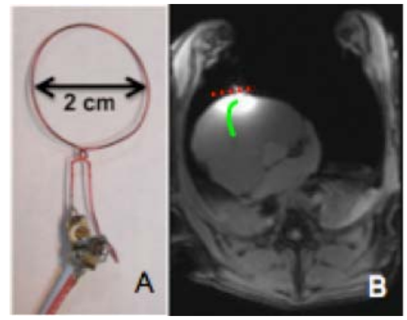

Figure 1: Coil setup. A. Coil design. B. Axial MR image from an open-chest animal study. The red dotted line represents the coil location and the green line the catheter.

Methods

A small (2-cm diameter) receive-only loop coil (Fig. 1A) was designed without passive circuit components in the loop to minimize image phase changes near the coil. Once the coil characterics were determined [3], the coil was covered with plastic (Parafilm, Pechiney Plastic Packaging Company, Chicago, IL) and placed on the surface of the right ventricle in the animal open chest cavity (Fig. 1B). Intracardiac RF ablations were performed using a novel, irrigated, temperature-controlled, 7F, 3-Tesla MR-compatible mapping and ablation catheter (MRI Interventions, Inc., Irvine, CA) positioned inside the right ventricle cavity against the lateral wall under real-time MRI-guidance provided by the IFE software (Siemens Healthcare, Erlangen, Germany).

Images were acquired on a 3T TIM Trio MRI scanner (Siemens Healthcare, Erlangen, Germany) using a segmented EPI pulse sequence with TE/TR = 6.0/10.9 ms, echotrain = 5, flip angle = 10°, acquisition time = 76.3 ms. The spatial resolution was 1 x 1 x 3 mm^3 and a FOV of 32 x 64 mm^2. The temporal resolution was one heartbeat when cardiac gating was used. The magnitude images were used to locate the catheter tip. The phase data was reconstructed and processed using MATLAB (Version 7.9; Mathworks, Inc.; Natick, MA). Longitudinal thermal maps were generated using both the reference (Fig. 2B) and referenceless (Fig. 2C) techniques [4].

Results and Discussion

High-resolution phase images were acquired in 76.3 ms every heartbeat using the local coil. Heating was observed within seconds of the delivery of RF energy (Fig. 2). Temperature maps from both the reference and referenceless calculations gave similar temperature evolutions over time in heart tissue using a 2^{nd} order 2D polynomial fit for the referenceless method. The temperature increase was determined to be approximately 25 °C as shown in Fig. 2D. The use of a local coil rather than external coils allowed the acquisition time to be shortened by at least 4 fold and the in-plane spatial resolution to be increased by at least 1.5 and still have adequate image quality (SNR) for temperature mapping.

Conclusions

This study demonstrates that using a local coil can make real-time MR thermometry high resolution *in vivo* in a beating heart possible and should enable real-time visualization of lesion formation. These results indicate that the development of intra-cardiac catheter-mounted local coils is justified. Improving and optimizing the acquisition and post-processing techniques are also part of our ongoing work.

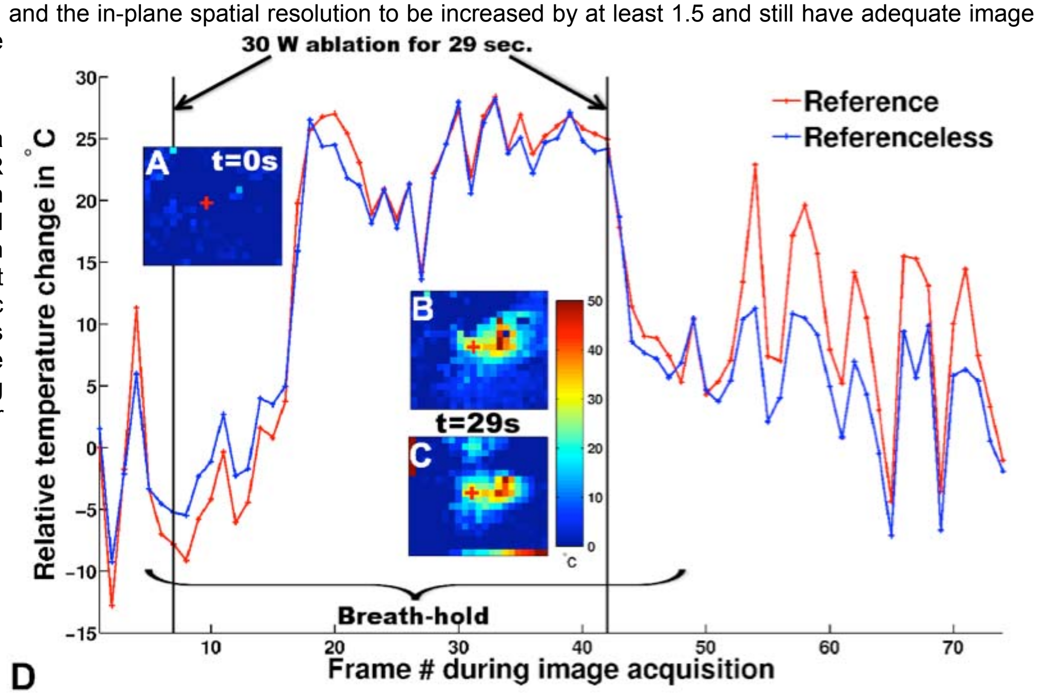

Figure 2: Limited FOV temperature measurements *in vivo*. A. Temperature map before any heating; B. Referenced map; C. Referenceless map in plane with the catheter at the end of ablation; D. Temperature evolution over time in single pixel (red cross in A, B, and C) approximately 3 mm away from the catheter tip where susceptibility artifacts are less pronounced.

References

[1] Vergara, G.R., et al. Heart Rythm, 2011. **8**: 295-303. [2]. Rieke, V., et *al.*, JMRI, 2008. **27**: 376-390. [3] Volland, N.A., et *al.*, 19th ISMRM Proc. 2011, 1764. [4] Rieke, V., *et al.*, MRM 2004. **51**: 1223-1231.

Acknowledgments

University of Utah Seed Grant 2011, MRI Interventions, Inc., Siemens Healthcare, and Ben B. and Iris M. Margolis Foundation.