Real-Time Volumetric MR Thermometry Aided by Motion Tracking using Tip Tracking Coils

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Introduction

MRI-guided RF ablation is a promising method for the treatment of atrial fibrillation. Proton resonance frequency (PRF) shift MR thermometry, which has been the method of choice, relies on the subtraction of intra-treatment phase images from that of a pre-treatment baseline phase image, making it very sensitive to motion. Referenceless [1] and multi-baseline [2] methods have been proposed and used to address motion-induced artifacts. These methods usually utilize 2D image registration and can only correct in-plane motion. In this work, a new method utilizing information from catheter-embedded tip tracking coils and Linear Phase Model (LPM) [3] is proposed to synthesize reference phase images for motion correction. The new method utilizes 2D multi-slice acquisition to facilitate volumetric temperature monitoring in the region of interest. The proposed method, allowing not only in-plane but also through-plane motion correction, would be beneficial to monitor thermal therapies in moving organs involving complex motion.

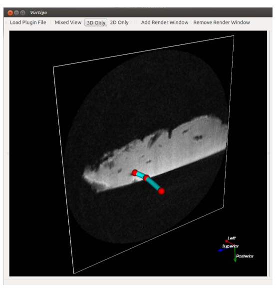

Figure 1: *Visualization of imaging plane and RF ablation catheter with tracking coils.*

Materials and Methods

In the development of MRI-guided catheter-based RF ablation methods multiple tracking coils were integrated into the catheter tip. The tip tracking was implemented using the 4-projection Hadamard method [4]. Assumption is that once the RF ablation starts the catheter does not move in relative to the target tissue and the motion detected by the tip tracking coils can be regarded as that of the moving organ. The visualization of one imaging slice and rendered catheter is shown in figure 1. The motion-corrected MR thermometry method employs the Linear Phase Model [3] and extends the multi-baseline method by establishing a linear relationship between motion vector and phase variation from the baseline images. Catheter tip tracking was interleaved with 2D multi-slice imaging. The motion-corrected volumetric data were constructed based on the realignment of 2D slices according to the motion vector associated with each slice imaging.

Experimental setup consisted of an excised *ex vivo* bovine liver and the RF ablation catheter with tracking coils placed in the liver tissue. All experiments were performed on a 1.5 T scanner (Signa, GE Healthcare, Waukesha, WI) using a modified 4-channel cardiac coil. A commercially-available RF generator (AngioDynamics Model 1500X, Latham, NY, USA) was used to deliver 8 Watts of power to induce ablation around the catheter tip. Periodic in-plane motion was induced by table rocker and random through-plane motion of about 1 cm was induced by hand on the scanner table to evaluate the performance of the proposed method. In order to achieve high temporal resolution, a multi-slice 2D fast gradient-echo spiral sequence with 16 arms was developed and used to acquire a 5-slice sagittal volume of 24x24x4 cm^3. The temporal resolution achieved was 380 ms per tracking and 1.9 s per volume acquisition.

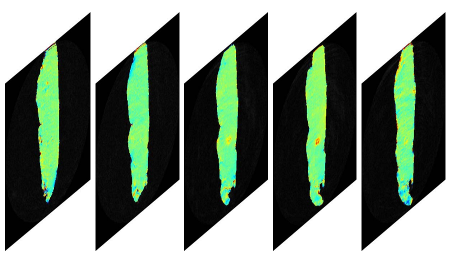

Figure 2: *Volumetric PRF phase mapping of bovine liver tissue under RF ablation in 1 min.*

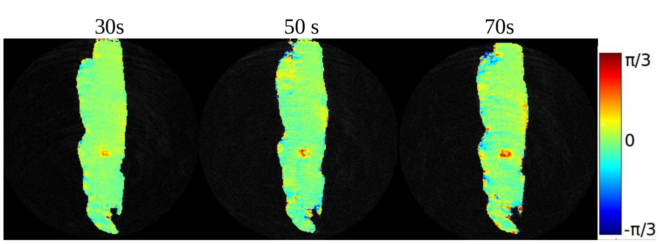

Figure 3: *PRF phase mapping of bovine liver tissue with RF ablation under through-plane motion.*

Results and Discussion

In the case of periodic in-plane motion, the performance of the proposed method was comparable to the convention multi-baseline method. Volumetric temperature mapping from the multi-slice acquisition is demonstrated for the through-plane motion in figure 2. Figure 3 demonstrates the evolution of ablation zone in time with RF ablation. The results show that the proposed MR thermometry method has good performance in the case of through-plane motion. In addition, the proposed method is computationally efficient, which is impoartant for real-time applications. For an acquisition matrix of 234x234x5 and 4 channel data, the 3D data realignment and baseline phase reconstruction took about 1 s for each volumetric acquisition on a general-purpose computer, which satisfied the need for real-time monitoring.

Conclusion

The proposed method employing tip tracking and Linear Phase Model may improve temperature monitoring when there is complex motion. Good in-plane and through-plane motion correction should allow prescription of imaging plane in any orientation. This method is computationally efficient, eliminating the need for image registration and therefore is suitable for real-time MRI-guided applications.

References: **[1]** Rieke V, *et al*, Magn Reson Med 2004; 51:1223-1231; **[2]** Vigen K, *et al*, Magn Reson 2003; 50:1003-1010; **[3]** De Senneville BD, *et al*, Magn Reson Med 2007; 57:319–330; **[4]** Dumoulin CL, *et al*, Magn Reson Med 2005; 29:411–415.