Phase-shift based magnetic resonance thermometry during motion

M. W. Vogel[1], S. janto[2], P. M. Pattynama[1]
[1]Department of Radiology, Erasmus MC, Rotterdam, Netherlands, [2]Department of Imaging Science and Technology, Delft University of Technology, Delft, Netherlands

Introduction

A particularly attractive method for this purpose is MR thermometry based on the proton resonance frequency (PRF) shift, which has been shown an accurate and precise technique. Whenever the imaged object remains stationary, temperature estimates better than 1.0°C can be achieved. However, when the object moves during the thermal therapy, substantial artifacts may significantly hamper the utility of the PRF based MR thermometry, because the susceptibility field in the object will change. Even still images at different positions exhibit large errors in the calculated temperature maps when using a single PRF reference image. In addition, there are motion-related phase terms that interfere with the PRF method. Therefore thermometry in moving targets is problematic. Current proton resonance frequency based methods compensate for motion-induced displacement, or selectively acquire data based on respiratory triggers, but fail to quantify PRF during motion. We hypothesized that these problems of incorrect temperature measurements might be overcome by using a modified single-shot EPI sequence. It was our aim then, to test the feasibility of acquiring accurate PRF based temperature measurements in moving objects.

Methods

We validated sensitivity for temperature changes in a moving phantom, comparing stationary to motion conditions, validated against a fiberoptic thermometer. Ex-vivo porcine liver tissue with a focally heated target point was heated to assess the stability of the PRF using the technique under continuous simple motion. Finally, in a healthy volunteer an experiment was performed to assess the stability of the proposed EPI sequence for complex motions.

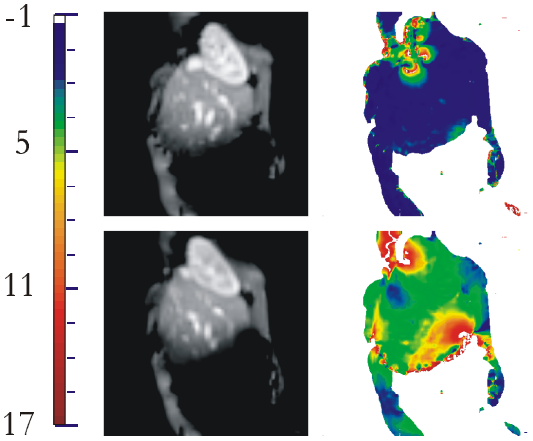

Figure 1 In a volunteer the temperature uncertainty (Standard deviaton from phase maps) is much reduced when with the proposed EPI sequence (top) versus regular EPI (bottom). In the temperature uncertainty maps (right), a mask was applied and values exceeding 16 °C were clipped. For reference of area, a similarly masked magnitude image (left) is presented for both sequences.

Results

The agreement between phase differences measurements versus temperature in stationary and motion condition was good (r^2=0.997, P<0.0001)) and covered the clinically relevant temperature range from approximately 40-70ºC. In the porcine liver, single pixel measurements during motion yielded a temperature uncertainty that was below 0.5 °C. The experiments in the healthy volunteer showed that the proposed sequence performed significantly better than a conventional EPI sequence. The observed average temperature error was below for 3.4°C for the regular EPI sequence versus 1.6 °C for the proposed sequence (figure 1).

Conclusions.

We conclude that for a target with periodic displacements in the field of view, we feel that the proposed technique is sufficiently stable to perform MR thermometry during motion.