Use of Fast-Spin-Echo MRI for MR Thermometry

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Introduction

Purpose
To investigate the feasibility of using a newly developed non-CPMG fast-spin-echo (FSE) sequence for MR thermography, based on the proton resonance frequency (PRF) based phase-shift method.

PRF-based MR thermometry is usually done using gradient recalled echo MR. Until recently, the FSE sequences have generally required CPMG-conditions and this has precluded their use in PRF-based MR thermometry – but the recently introduced non-CPMG FSE sequences may obviate this problem. The non-CPMG sequence used here¹ (figure 1) keeps the standard gradient waveforms of the CPMG FSE, but employs a quadratic phase modulation of the train of refocusing RF pulses.² Contrary to other non-CPMG methods³,⁴ which reduce the available signal by half, it utilizes the full signal.

Theoretically, FSE MRI should have advantages over gradient-echo MRI because of better signal to noise ratio and lower sensitivity to magnetic field inhomogeneities.

Methods

We tested the temperature sensitivity of a non-CPMG FSE sequence in an in vitro setup, validating the MR measurements with absolute temperature measurements obtained with a fiberoptic thermometer (Luxtron 790, Santa Clara, USA). A phantom of gel was homogeneously heated in a water bath and allowed to cool while continuous measurements were obtained (figure 2). The experiment was repeated 4 times. MRI was done on a 1.5T system (General Electric CV/i, LX 8.4 software, with 40mT/m gradients and 150 Tm⁻¹s⁻¹ slew rate) using the following parameters for the single-shot non-CPMG FSE sequence:

TEeff/τ/TR/BW= 63/15/4000/63, fatsat, FOV 240x240mm, matrix 256x256, NEX=1 and slice thickness of 10mm. τ is the time added to the half TE to encode temperature information. Off-line temperature maps were created using IDL 5.3 software package (IDL, Boulder, CO, USA). Temperature maps were validated with the reference using SPSS 8.0 (SPSS, USA), using small regions of interest (5x5 pixels).

Results

The MR-based temperatures correlated well with absolute temperature measurements (figure 3); temperature related phase evolution was -0.051±0.001 - Temp - 0.005±0.004 with R²=0.99, SEE=0.012. The temperature range was 44-52 degrees Celsius. The method was reproducible, and appeared not to suffer from expected susceptibility effects near the air-gel interface with regard to the temperature information, a phenomenon that has been reported elsewhere using gradient echo sequences.⁵

Discussion

We have shown the feasibility of using a non-CPMG FSE sequence for PRF-based MR thermometry. Based on this preliminary study, the method appears to have favorable sensitivity for temperature changes combined with good reproducibility and stability. Further studies are warranted to test this method in the in vivo setting.

References