Field drift compensation for MR thermometry using independent field probe measurements

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Introduction

Stable MR thermometry is key for MRI guided high intensity focused ultrasound (MR-HIFU) hyperthermia or ablation procedures and plays an important role in safety validation of MR hardware. For MR-HIFU, ablative sonications are performed within 10 seconds to a few minutes [1], hyperthermia procedures will require substantially longer exposure of the tissue to heat. For local drug delivery applications, using thermosensitive liposomal preparations for example, hyperthermia cycles of over ten minutes have been applied [2], and pharmacokinetic models suggest that exposures of over 30 minutes may be desirable [3]. In addition, the small temperature increase to only 42°C, requires MR thermometry to be particularly accurate.

An important cause of systematic error in proton resonance frequency shift (PRFS) based MR-thermometry [4] is drifting of the main magnetic field over time. Field drifts cause phase shifts that the PRFS method interprets as temperature change. Recently, field probes have been used to measure temporal field variation due to eddy currents and physiological variations [5,6] In this abstract, we demonstrate the use of field probes for drift correction of PRFS-based thermometry.

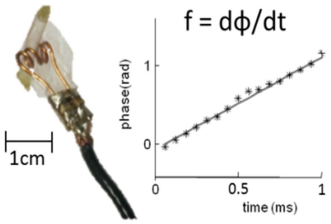

Figure 1: A small field probe (left), was used to independently measure the frequency by fast pulse-acquire readout and a linear fit to the phase (right) to assess the magnetic field drift over time during other sequences.

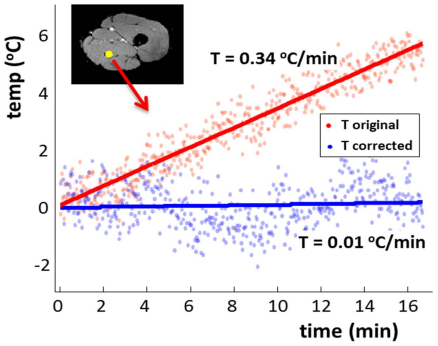

Figure 2: temporal temperature offset without heating in one pixel caused by field drift without (red) and with (blue) field probe based correction.

Methods

A 1.5T MRI was equipped with a single field probe; a small homebuilt ^{1}H-receiver coil, surrounding a cylinder containing tap water (fig. 1). The field probe was placed in the bore to monitor field drift independent of the imaging sequence. The 1ms pulse-acquire field measurement was interleaved with a standard temperature imaging sequence; (multishot EPI, 3 slices, dynamic scan time 1.9s, voxel size 2.5x2.5x7mm^3, TR/TE 36/19ms FOV 450x400mm^2) Five hundred image sets were acquired for a total scan duration of 16 min. Temporal drift was measured in the upper legs of a volunteer. The field drift information was stored and the data was corrected in retrospect. As a measure of stability the standard deviation of temperature over time was calculated on a per pixel basis.

Results

Up to 5.4°C of erroneous temperature increase was observed during a 16 minute scan due to magnet drift (figure 2). After field probe correction the temperature increase was minimal. The temporal stability of the temperature without drift correction (figure 3a) was greatly increased with field probe based drift correction (figure 3b). Results were comparable to the current standard, correction with data from a manually selected ROI (figure 3c).

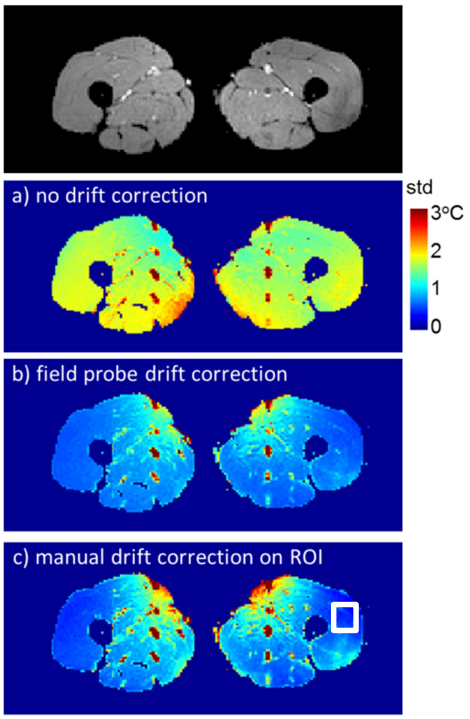

Figure 3: Temporal field stability (Standard deviation over time) without drift correction (a), with field probe based correction (b) and with manual ROI selection and correction (c)

Discussion and Conclusion

Magnetic field drift has been a long standing problem for accurate temperature imaging, which is essential in for example for MR-HIFU. Traditionally, drift is corrected by choosing an ROI outside the heated area and subtracting the phase changes in this ROI from the phase change in the area of interest. It is however not always possible to define such an ROI at sufficient SNR, and the outcome of this procedure may be user dependent. Alternatively, referenceless methods have been proposed that rely on the heating to be local and phase behaviour over the image to be smooth [7], which are also not easily applicable if only small or noisy referencing regions are available in the image. Here we show that accurate, easy and user independent drift correction is possible with information from field probes in the bore.

References:

1. F.M. Fennesy, Radiology 2007
2. M. de Smet, J Control Release 2011
3. A. Gasselhuber, Int J Hyperthermia 2012
4. J. de Poorter, MRM 1995
5. N. de Zanche, MRM 2008
6. V.O. Boer, MRM 2012
7. V. Rieke, MRM 2004