Automatic B0 Drift Correction for MR Thermometry

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Introduction

Local destruction of brain tumors through minimally invasive stereotactic techniques has been investigated clinically using various energy sources, including radiofrequency, high intensity focused ultrasound, and in particular laser [1, 2]. Magnetic resonance imaging not only provides excellent soft-tissue contrast, but also is sensitive to thermal effects making it an ideal modality to monitor and guide these procedures. Temperature changes can be calculated online using the proton resonance frequency (PRF) method [3] which exploits the fact that the phase of the MR signal is proportional to the temperature of the observed tissue.

From Equation 1, it follows that PRF-derived temperature measurements are sensitive to patient motion and B0 drifts. As the patient's head in these procedures is fixed by a stereotactic frame we do not have to correct for motion. However, a gradual drift of the B0 field occurs (see Figure 2, red points) resulting in additional phase drift that must be accounted for. In the following, we introduce a method which automatically corrects for this drift with no need for user interaction.

$$\Delta T(x,y,t) = \frac{\varphi - \varphi_{ref}}{\gamma\, \alpha\, B_0\, TE}$$

$\Delta T(x,y,t)$: relative temperature change for a voxel at position (x, y) and time t
φ: initial phase before heating
γ: gyromagnetic ratio (42.58 MHz/Tesla)
α: temperature sensitivity coefficient (−0.01ppm/°C)
B_0: main magnetic field strength in Tesla
TE: echo time in ms

Equation 1: Relative temperature calculation using proton resonance frequency shift.

$$\Delta T(x,y,t) = \frac{(\varphi - \varphi_{ref}) - \overline{\varphi}_{drift}}{\gamma\, \alpha\, B_0\, TE}$$

Equation 2: B0 drift correction.

Methods

The mean phase drift is often calculated from an area which is not heated and thus remains at reference temperature [4]. However, this region can be difficult to place and its location and size highly influence the effectiveness of correction.

To overcome this problem, we propose to automatically determine the mean phase drift from all voxels which show a standard deviation smaller than a threshold *th* in the phase. That is, all voxels having a standard deviation from the reference temperature (usually 37.2 °C) smaller than *th* are included in the calculation of the mean phase drift $\overline{\varphi}_{drift}$. The relative temperature change $\Delta T(x,y,t)$ is then calculated as described in Equation 2. For MR thermometry in the brain, we propose a threshold based on the phase change per °C, i.e. $th = \gamma\, \alpha\, B_0\, TE$.

For validation of the proposed B0 drift correction algorithm, MR thermometry was performed on the brains of four volunteers (10 measurements) using a 1.5T scanner (MAGNETOM Espree, Siemens Healthcare, Erlangen, Germany). For continuous MR thermometry, the healthy volunteers' heads were positioned in a 12-channel head matrix coil with foam cushions to minimize motion. Using a gradient echo PRF sequence (TE = 17 ms, TR = 156 ms, resolution = 2 x 2 x 2 mm, flip angle = 25°) we continuously imaged over 13 minutes to monitor the gradual B0 field drift. The volunteers gave their written consent to the study.

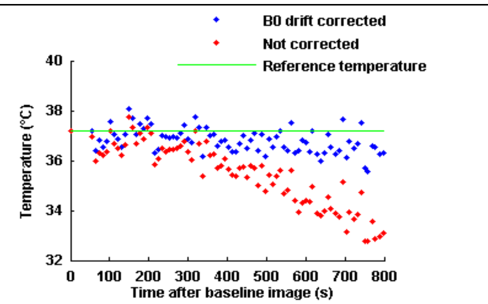

Figure 2: Plot comparing the uncorrected temperature over time with the one corrected for B0 field drift in a randomly selected voxel in the frontal lobe of a brain.

Results

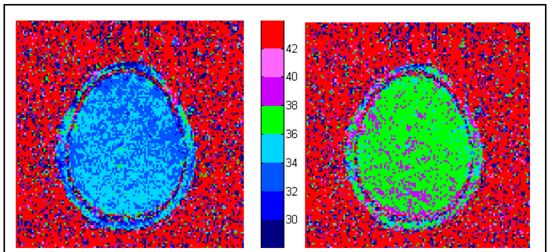

Figure 1: Temperature map after 13 min of continuous PRF imaging with no B0 field drift correction applied (left) and proposed automatic approach (right). Reference temperature was set to 37.2°C. As no heat/cold was applied, there was no temperature drop as suggested by the uncorrected temperature map (left) but the map is corrupted by B0 field drift which is corrected for by the proposed approach in the right temperature map.

Results from this study demonstrate that the proposed method successfully corrects for zero-order phase drifts during MR thermometry (see Figure 1 and 2). In Figure 1 the uncorrected temperature map after 13 min of PRF image acquisition is compared to the B0 drift corrected one. The temperature over time for a voxel randomly selected in the frontal lob of the brain is plotted in Figure 2.

Table 1: Mean absolute deviation from reference temperature (in °C) over a 13 min PRF image acquisition period. Comparison between uncorrected temperature and temperature corrected for B0 field drift.

Volunteer Number	Uncorrected	Automatic B0 Correction
1	1.65 ±0.67	0.50 ±0.55
	1.10 ±0.09	0.27 ±0.09
	1.62 ±0.47	0.44 ±0.35
	1.62 ±0.50	0.43 ±0.39
2	0.80 ±0.42	0.28 ±0.41
	0.78 ±0.44	0.28 ±0.43
3	1.75 ±0.88	0.60 ±0.84
	1.02 ±0.07	0.21 ±0.06
	0.52 ±0.20	0.37 ±0.20
4	0.67 ±0.48	0.33 ±0.48

Conclusion

The proposed B0 field drift correction approach significantly improves the precision of PRF temperature measurements in the brain without the need of defining a ROI of interest for B0 drift correction or an additional stable reference.

References

[1] Carpentier et al. Neurosurgery, vol. 63, pp. 21-29, 2008.
[2] Goldberg et al. AJR, vol. 174, pp. 323-331, 2000.
[3] Ishihara et al. MRM, vol. 34, pp. 814-823, 1995.
[4] De Poorter et al. JMRI, vol. 103, pp. 234-241, 1994.