High Speed Multi-Voxel Thermography with Free Induction Decay Echo Planar Chemical Shift Imaging

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Introduction:

Fever is associated with poor outcomes in stroke [1]. Direct monitoring of brain temperature would be optimal as differences of 1-2 °C between brain and body core temperature are observed in stroke cases [2]. Conventional monitoring has the disadvantage of being an invasive procedure and only being able to sample one brain location [2]. Proton chemical shift imaging (CSI) offers a potential of noninvasively and simultaneously measuring brain temperature in multiple locations [3]. However, the clinical utility of this method is diminished by long acquisition times. [3]. Recently, a method of free induction decay echo planar chemical shift imaging (FID EP-CSI) was introduced which is approximately 12 times faster than conventional CSI [4, 5]. In this study we evaluate the potential of using FID EP-CSI to measure temperature in a phantom study.

Methods:

A 14 cm diameter, 2.4 L cylindrical phantom was filled with Ringer's lactate and 10 mM of N-acetyl-aspartate (NAA) The phantom was heated to 38 °C and allowed to cool to 29 °C during which time 13 FID EP-CSI single slice acquisitions on a 3T Philips Achieva scanner (R 1.7.1, Philips Medical Systems, Best, The Netherlands) were performed. Each consisted of 2048 gradient echoes (1024 even and 1024 odd) with the following acquisition parameters: TR=1500 ms, NSA=1, sampling frequency 1350 Hz, 1024 data points, matrix size 16x16, slice thickness 15.6 mm, field of view 25 cm x 25 cm, total time 28s. Temperature was continuously monitored in the phantom with two fluoroptic probes (Luxtron, Mountain View California, United States). Water frequency for each spectrum was determined using AMARES [6] in jMRUI [7]. NAA frequency was determined by first performing post processing water suppression with maximum phase linear filtering [8], and then identifying the NAA peak between 2.5 and 2.9 ppm as the maximum of the modulus of the complex spectrum after zero-padding the water-suppressed FIDs from 1024 to 16384 samples. The difference between NAA and water frequency, in ppm, was then compared to the continuously monitored temperatures, averaged over the duration of the acquisition.

Results:

Fig. 1 shows non-water suppressed (A), and water suppressed spectra at 37.8 °C (B) and 29.3 °C (C) temperatures and from the same voxel. Data from the two temperature probes, which was not significantly different, was averaged. R^2 values of the linear regression of NAA-H_2O frequency difference vs temperature for individual voxels are shown in Fig. 2. The voxels for which R^2>0.99 are outlined in white. Measurements from individual voxels for which R^2>0.99 are shown in Fig. 3. The equation for the best linear least squares fit (±95% confidence intervals, R^2=0.9967) was $T = (100.67 \pm 1.07) \cdot \Delta_{NAA-H_2O} + (300.36 \pm 2.86)$ where T is temperature and Δ_{NAA-H_2O} is the frequency difference, in ppm, between NAA and H_2O. The rms error between predicted and temperature measured by the probes was 0.16 °C.

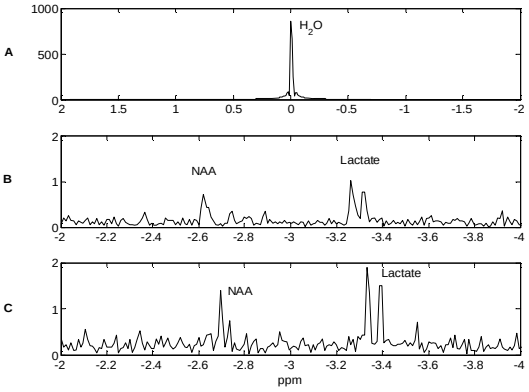

Figure 1: A) Non water suppressed absolute spectrum,. **B)** Water suppressed absolute spectrum at 37.8 °C from same voxel, and **C** Water suppressed absolute spectrum at 29.3 °C from same voxel.

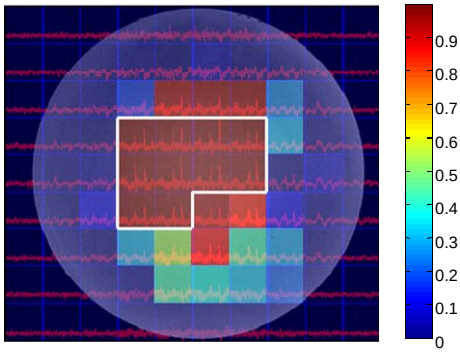

Figure 2: T2 weighted MRI of NAA phantom with overlying spectra (at 37.8 °C acquisition). Voxels are color coded by R^2 of linear regression fit for NAA-H_20 frequency shift vs. temperature. Voxels for which R2>0.99 are outlined in white.

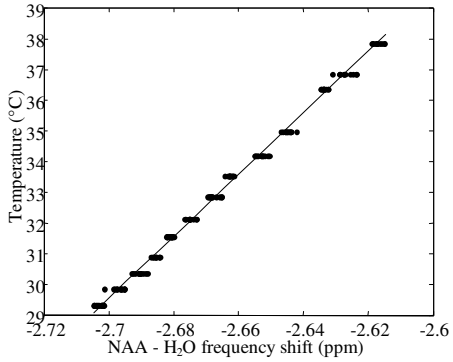

Figure 3: Least squares fit for relation between NAA-H2O frequency shift and temperature.

Conclusion

Feasibility of quickly obtaining non-invasive temperature maps by FID EPCSI has been established in a phantom model. Temperatures were obtained with precision of approximately 0.2 °C in less than 30 seconds of acquisition time with resolution of 1.6 cm. Fitted regression coefficients were similar to those from obtained from other studies [9, 10]. To our knowledge, this is the first incidence of the use of this method for thermography. These results suggest FID EP-CSI could be used to measure temperature in human and animal studies.

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