Breast Temperature Mapping Using Model-Based PRFS Method

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Introduction

MR-guided thermal therapy techniques utilizing laser, RF and focused ultrasound have been used in the ablative treatment of breast cancer (1-3). MR thermometry method based on proton resonance frequency shift (PRFS) is a promising noninvasive tool for real-time temperature monitoring. However, the conventional phase mapping based PRF method is very sensitive to motion, e.g., respiratory motion, magnetic field drift, and widely distributed fat species in the human breast. A temperature model using fat as an internal reference has been proposed in our previous work to overcome the problems associated with the traditional PRF (4). In this work, the method is applied in the human breast. The model and the related algorithm are modified to be able to distinguish more than two species in the area we examine and tolerate the relatively poor quality of breast images we obtained. The feasibility of the modified method is demonstrated through a preliminary *in vivo* experiment of a healthy volunteer.

Method

Signal model: Our original model using fat as the internal reference is fitted into the signal by the extended Prony algorithm to estimate the chemical shift between water and fat which contains absolute temperature information. However, in most tissues there are more than two species. In the human breast, besides water (4.7ppm) and methylene [-$(CH_2)_n$-] (1.3ppm), several other species like methyl (0.9ppm), methylene (2.2ppm), olefinic hydrogens (5.2ppm) and choline (3.2ppm) also contribute to the breast spectrum. In this situation, the original two-component signal model (4) is no longer suitable. Therefore, the model is modified to contain multiple components $s(TE_n) = \sum_{i=1}^{K} \rho_i e^{j\phi_i} e^{(-R_{2,i}^{*} + j2\pi f_i)TE_n}$, where the number of detectable species K depends on the composition of local tissue at each voxel.

Algorithm: To solve the problem above, we first decompose the covariance matrix obtained from the extended Prony algorithm by SVD and choose the largest K singular values above a predetermined threshold. Secondly, an adaptive inverse filter (5) is used in order to improve the precision of parameter estimation at low SNR. Then the new filtered data are used to recalculate the covariance matrix and the value of K is updated which makes the modified algorithm perform in an iterative fashion. After the computation at each voxel, a most suitable spectrum is extracted for each voxel by minimizing the norm of the difference between the calculated K frequencies and prior known breast spectrum. This match procedure takes into account the joint frequency shift along the spectral axis due to field inhomogeneity and the frequency alias due to non-adequate spectral bandwidth acquired by the multi-echo GRE sequence.

***In vivo* experiment:** MR thermometry was performed in a 1.5T scanner (Sonata; Siemens Medical Solution, Erlangen, Germany). A healthy 25-year-old woman was placed in prone position and a two-element receive-only breast coil was used for coronal image acquisition under constant room temperature. The imaging parameters of 12-echo GRE sequence were TE_0/ΔTE/TR/BW/Flip Angle/FOV/Slice Thickness/Data Matrix=3.5ms /3.44ms/60ms/±38.4kHz/25°/25cm×25cm/5mm/128×128. Twenty consecutive images (each in a scan time of 8s) were acquired with breath hold. The data of right breast from a single coil element and temperature coefficient of -0.01ppm/°C were used for data analysis.

Results

Fig.1 shows the magnitude image of both breasts, and the water and fat masks of the right breast calculated by our method. The result indicates that the majority of voxels in the breast contains both water and fat, referred to available voxels. The maximum, minimum and average proportions of available voxels in all the breast tissue voxels in the 20 measurements are 61%, 57% and 58%, respectively. Fig. 2 shows the spatial temperature maps relative to the room temperature (corresponding chemical shift is 3.41ppm computed by averaging all available voxels) at three different time points. Fig. 3 shows the relative temperature evolutions of three sample regions within the breast (red, blue and black arrows point to region 1-3 respectively) which are calculated by our method.

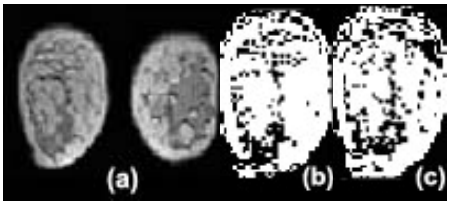

Fig.1: Image of both breasts (a) and masks of water (b) and fat (c).

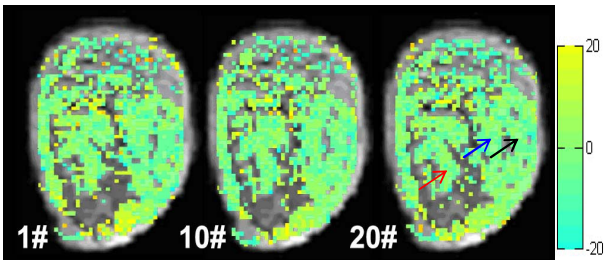

Fig.2: Three spatial temperature maps relative to the room temperature.

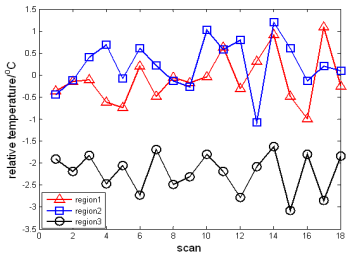

Fig.3: Relative temperature evolutions of three sample regions.

Conclusion

The modified model and algorithm are able to distinguish multiple chemical species and suitable for low SNR images. The preliminary results of *in vivo* experiment indicate the capability of our internal reference model based method in breast temperature mapping.

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