Dynamic 3D MR Thermometry in thoracic vertebrae using Controlled Aliasing in Volumetric Parallel Imaging (2D CAIPIRINHA)

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Target audience: Radiologists and scientists working on MR thermometry.

Purpose: Microwave ablation is an effective therapy used to treat diseases such as bone tumors in vertebra where the tumors grow in depth. Performing this procedure under the guidance of MRI makes it possible to monitor the temperature during the treatment. Volumetric temperature maps are required with large volume coverage of the diseased tissues and the surrounding healthy tissues, especially spinal nerves. However, 3D volumetric imaging is relatively slow in acquisition. In this work, we developed an accelerated dynamic 3D MR temperature estimation method based on 2D CAIPIRINHA [1] in order to obtain better temperature estimation accuracy while significantly reducing the acquisition time at a reduction factor of four.

Methods: Conventional uniform undersampling and 2D CAIPIRINHA type undersampling [1] were performed with $2\times$ phase encoding direction-acceleration and $2\times$partition encoding direction-acceleration respectively. The 3D TFE sequence was implemented to acquire data in a 3.0T Phillips scanner (Philips, Best, the Netherlands) and SPIRiT [2] was used to reconstruct the down-sampled kspace. Temperature maps were calculated using proton resonance frequency shift method [3] based on a fully-sampled reference.

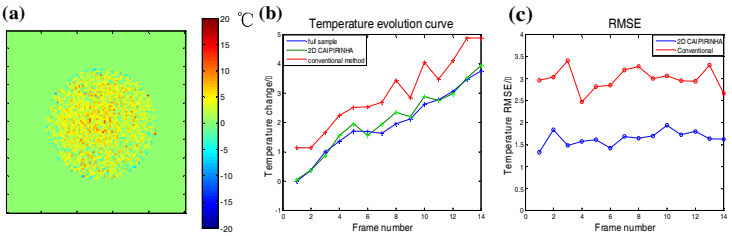

Fig1 ***Phantom experiment****: Temperature change map of the phantom* ***(a)****. Comparison of 2D CAIPIRINHA and conventional method (R=4) for temperature estimation with fully-sampled references* ***(b)*** *and RMSE* ***(C)*** *of ROI (10×10 pixel).*

Table1

In-vivo heating simulation experiment*: Temperature Root-Mean-Square Error (RMSE) of 2D CAIPIRINHA and conventional method*

RMSE/℃	Sagittal plane	Coronal plane	Axial plane
2D CAIPIRINHA	1.48	1.55	1.52
Conventional method	2.46	2.92	2.26

A phantom experiment was performed on a 1% agar phantom with a heating process and the procedure of the temperature change was scanned using an 8-channel head coil. In-vivo simulations were performed to simulate a heating process of the heating target (bone trabecula) and the surrounding tissues such as spinal cord. In-vivo non-heated experiment was also performed using the conventional method and the proposed method respectively on a healthy volunteer using a 32-channel SENSE Torso/Cardiac coil. The two phase encoding directions were in the AP and the SI direction. Imaging parameters for phantom experiment: acquisition matrix size = 100 × 100 × 30, FOV = 160 mm × 160 mm × 77 mm. In-vivo simulation experiment: acquisition matrix size = 187 × 148 × 50, FOV = 300 mm × 237 mm × 128 mm, the heating target was heated to 67℃. In-vivo non-heated experiment: acquisition matrix size = 200 × 160 × 50, FOV = 320mm × 256mm × 128mm. All experiments use TR = 8ms, TE = 5ms, flip angle = 12°.

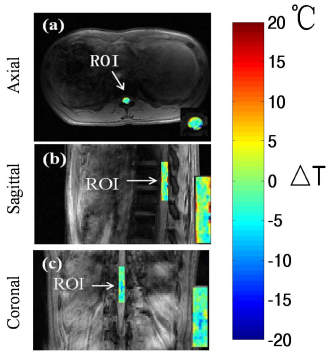

Fig2 In-vivo non-heated experiment: *Three orthogonal views of the subject and the corresponding temperature change maps at the Regions of Interest (ROI) using 2D CAIPIRINHA* ***(a,b,c)****. Bottom right corner: the zoomed temperature change maps of ROI.*

Results: The results of phantom and in-vivo simulation experiments are shown in Fig1 and Table1. The temperature evolution curve of 2D CAIPIRINHA agrees well with fully-sampled data (Fig1 (b)) with a temperature RMSE of 1.5℃. Fig2 shows the location of Region of Interest (ROI) in three orthogonal views and the corresponding temperature maps of ROI in in-vivo non-heated experiment. The spatial standard deviations of ROI in dynamic study are shown in Fig3. The average spatial standard deviation of this method is 1.67 ℃ which is much less than the conventional undersampling method of 3.30℃.

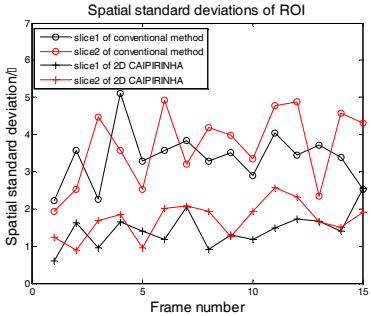

Fig3 In vivo non-heated experiment*: Spatial standard deviations of ROI using 2D CAIPIRINHA and conventional method (R=4).*

Discussion: Both the agreement of the temperature evolution curves in phantom experiment (Fig1 (b)) and the results of in-vivo simulation experiments (Table1) demonstrate the feasibility of this method for monitoring change of temperature with higher temperature estimation accuracy. The results of in-vivo non-heated experiment show the advantages of this method for monitoring the temperature of tissues around spinal cord with a large volume size of 320mm × 256mm × 128mm.

Conclusion: We validate the feasibility of 2D CAIPIRINHA for monitoring the temperature change with large volume coverage while reducing the acquisition time by a factor of four. This method can be applied to monitor the temperature change of spinal cord with good accuracy.

References:

[1] Breuer, F. A. et al., MRM,2006 [2]Lustig, M. et al.,MRM,2010[3] Ishihara et al., Magn Res Med 1995; 34: 814-823.