Improving the referenceless MR thermometry using adaptive ROI

Changjun Tie[1], Chao Zou[1], and Xin Liu[1]

[1]*Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, Guangdong, China*

Introduction Referenceless or reference-free MR thermometry is a motion-insensitive proton resonance frequency shift thermometry method. The method obtains the baseline phase of region of interest (ROI, containing heated region) from a region of reference (ROR) and doesn't require the acquisition of baseline images. Several referenceless methods have been modified from the originally proposed referenceless method. However, the accuracies of these methods related to the size of ROI have not been concerned. The ROI/ROR are drawn manually around the heated region in the previously proposed referenceless methods. The ROI size should be large enough to contain the whole heated region with the ROI identical through all measurements. This may have two main disadvantages: the size of heated region is hard to estimate before ablation during the real-time monitoring. Furthermore, larger ROI usually results in worse accuracy for referenceless methods [1]. The accuracy of temperature images with small heated region is therefore compromised. This work proposes to use adaptive size of ROI for real-time referenceless thermometry. The size of ROI is decided by the size of heated region, which is measured from previous temperature map. The results would increase the accuracy of referenceless methods and improve the automation of referenceless thermometry for real-time monitoring.

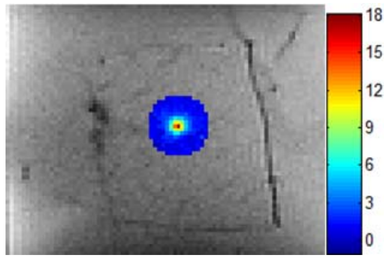

Figure 1 Temperature map duration HIFU ablation experiment

Materials and Methods All experiments were conducted on a 3T MR system (Siemens TIM Trio, Erlangen, Germany). Temperature imaging was performed with a 2D gradient echo (GRE) sequence. Basic imaging parameters were: TR/TE = 25/10ms, spatial resolution = 1.5×1.5×3.0 mm^3, flip angle = 10^o, bandwidth = 160 Hz/pixel, matrix size=192×192, measurement = 50. A water excitation pulse was used for fat suppression. The e*x-vivo* heating experiments were conducted in the porcine muscle using an MR compatible HIFU prototype system. The ablation started from 11^{th} to 19^{th} measurements.

Three referenceless methods including complex field estimation (CFE) [1], near harmonic (NH) [2] and phase finite difference (PFD) [3] written in MATLAB (Mathworks, NATICK, USA), were evaluated with the adaptive ROI method compared to fixed ROI size = 6/14 pixels. ROI/ROR was set to be circle around focus point. For adaptive ROI scheme, the heated region size σ is characterized as the distance from the peak to the 1/e drop point [1]. The ROI size for next measurement is then set to $max(4\sigma, r_{min})$ with $r_{min} = 4$ in our experiment. The area ratio of ROR/ROI was fixed to 1.0. Polynomial order = 2 for CFE and PFD. Temperature error is defined as the difference between that method and the reference subtraction (REF) method with field correction since there was no motion during the experiments. Temperature accuracy was assessed by the root of mean squared error (RMSE) all over the ROI.

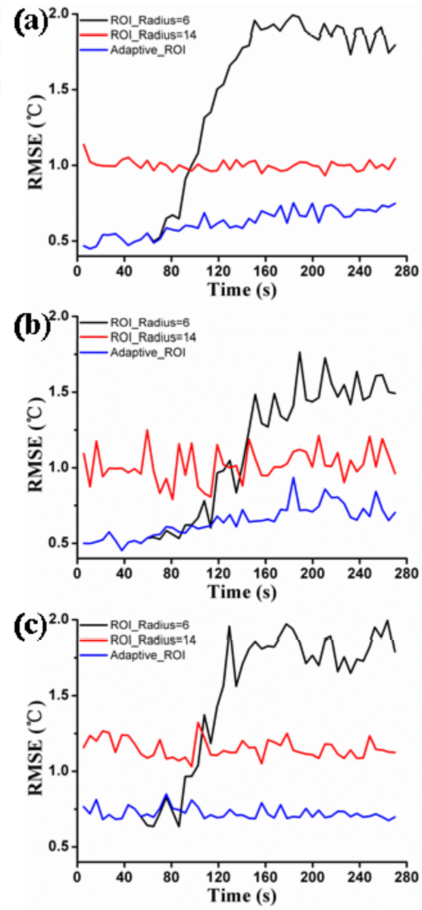

Figure 2 Temperature estimation error of three methods ((a) PFD, (b) NH and (c) CFE) with adaptive and fixed ROI

Results Figure 1 shows a temperature map duration HIFU ablation by REF method. Figure 2 shows the temperature error of three methods using adaptive ROI and fixed ROI = 6/14 pixels for three methods in all measurements. All the three methods show that the measurement accuracies are consistently improved by using adaptive ROI. Before the heat was started, all methods favored small ROI due to less fit error, and the results of adaptive ROI were similar to fixed ROI size = 6. With heat going on, the error of small ROI became larger since the heated region was larger than the small ROI. Errors of ROI size = 14 are larger, but consistent in all measurements for the three methods. The profiles of temperature change at the HIFU focus are shown with good agreement between referenceless methods using adaptive ROI scheme and REF method in Figure 3.

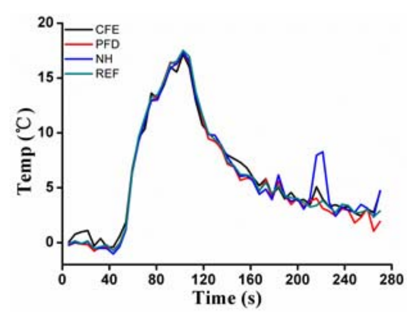

Figure 3 Temperature change at the HIFU focus by REF, CFE, PFD and NH methods with adaptive ROI.

Discussions and conclusions For PFD and NH method, the measurement errors are more sensitive to the size of ROI. The ROI size starts to enlarge with heat diffusion to larger area, which results in the increase of measurement error after heating. This may be improved by optimizing the relationship of heated region and ROI size further. Measurements between 210-230s of NH method show large discrepancy from REF, which is also found in pixels around focal point and also in fixed ROI scheme. This may result from the incorrect estimation of background phase from ROI boundary.

The adaptive selection of ROI size increases the accuracy of referenceless methods. Most referenceless methods assume a large ROI since the heated region is unknown before heat occurs, which compromises the accuracy in some measurements. More importantly, it may facilitate the automation of referenceless methods for real-time monitoring during ablation. The size of ROI is no longer to be manually fixed before heating. Using the adaptive ROI scheme, the heated region size is estimated from current temperature image, and it is automatively applied to the ROI size of the next measurement.

References 1. Kuroda, K. et al.MRM 2006, 56, 835-843. 2.Salomir, R. et al. IEEE TMI 2012, 31, 287-301. 3.Chao Zou. et al. PMB 2013,58:5375.