An automatic real-time optimization of MT off-resonance frequency

Jyun-Ming Tsai[1], Teng-Yi Huang[1], Hsu-Hsia Peng[2], Yi-Chun Wu[3], and Fu-Nien Wang[2]

[1]Electrical Engineering, National Taiwan University of Science and Technology, Tapei, Taiwan, [2]Biomedical Engineering and Environmental Sciences, National Tsing Hua University, Hsinchu, Taiwan, [3]Molecular Imaging Center, Chang Gung Memorial Hospital, Taoyuan, Taiwan

Introduction

This study presents an automatically real-time feedback optimization for frequency adjustment of magnetization transfer imaging. The frequency setting is a crucial parameter of MT-based imaging. For example, amide proton transfer (APT) imaging has been shown promising to measure tissue pH. Magnetization transfer asymmetry (MTasym) is a typical approach for quantitative APT analysis. However, B0 inhomogeneity introduces errors of the MTasym method. Obtaining frequency offsets induced by B0 inhomogeneity can improve the accuracy of APT imaging [1]. Another example is the MT contrast dependency on the saturation frequency. A previous investigation utilized MT imaging to quantify tissue damage in high-intensity-focus-ultrasound (HIFU) thermotherapy [2]. To obtain optimal MT contrast, they employed a "sweep scan" to perform MT imaging with a range of frequency offsets and determined the optimal frequency according to MT contrast. In this study, we proposed a general framework that can automatically optimize MT frequency based on the obtain image. The optimization can account for a whole field-of-view or a specific region-of-interest (ROI). We demonstrate this system by an experiment calibrating the central frequency of MT pulse for a ROI.

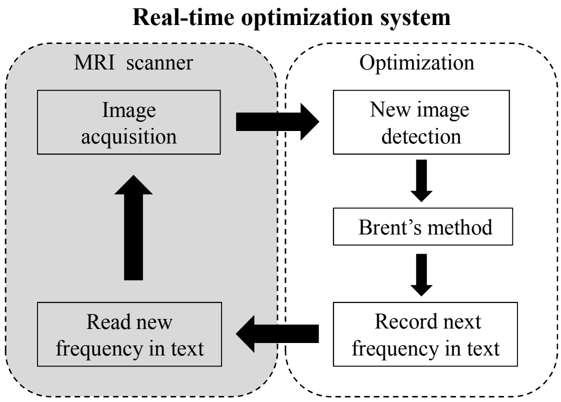


Fig. 1 The flow-diagram of real-time optimization system.

Material and Methods

The automatic real-time optimization system [3] includes two procedures: (1) immediately transferring the acquired images from MRI scanner to a personal computer (PC) and (2) optimization algorithm for MT frequency. Figure 1 shows the flow diagram of the proposed real-time system. By modifying the configuration of the Image Calculation Environment (ICE, Siemens, Germany) and connecting the scanner with PC through Ethernet connection, the images are transferred to PC immediately after data acquisition. The optimization algorithm is the Brent local searching method based on quadratic interpolation. The "cost function" depends on goals of the optimization. The optimal frequency anticipated by the Brent method is then sent back to the scanner for the next image acquisition. The aforementioned procedures form a close loop, and the iteration loop stops when the algorithm reaches a preset convergence criterion.

In the demonstrating experiment, the optimization goal is to find a precise central frequency in a ROI. A calibrated central frequency is potentially useful to obtain a more precise MTasym and accurate APT analysis. The optimization algorithm was designed to adjust MT frequency which minimizes mean signal intensity of a ROI in the MT images. The system was tested on a 3T whole-body MR system (Siemens, Tim Trio, Germany) during a follow-up study of a rabbit undergoing HIFU thermotherapy on its leg muscle. This experiment was performed in accordance with institutional guidelines governing the use of research animals. Before the experiment, the rabbit was anesthetized using isoflurane and was placed in a right- or left-lateral position. Two sets of MT-prepared gradient-echo images were acquired for the rabbit. One was a real-time optimization acquisition with initial offset frequencies of (-200, 0, 200) Hz. The other was a sweep scan which the optimal frequency was the center and covered the range of the center ±1000 Hz with step size of 100 Hz. The imaging parameters were (TR/TE/flip angle: 23ms/3.61ms/25°,matrix size: 128x128). The ROI for optimization was first selected on the rabbit leg muscle in a pre-acquired image. And the following scans working with optimization system were performed with inter-scan interval of 1 second.

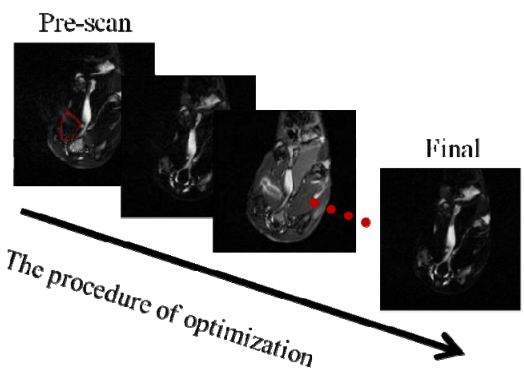
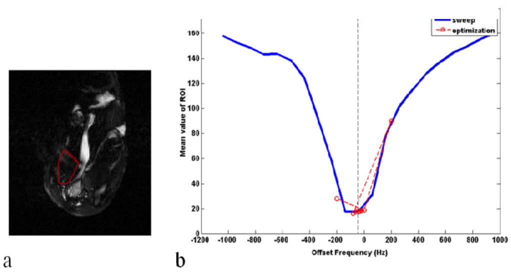


Fig. 2 The diagram of optimization process.

Results

Figure 2 shows the images obtained during the procedure of optimization. The region of interest shows progressively darker. The mean signal intensities of the obtained images during real-time optimization are displayed in Fig.3b (red circle). After Brent's local searching method, the result of -40 Hz was associated with lowest signal intensity of the selected ROI (Fig.3a, ROI outlined by a red polygon) and was therefore considered as optimal MT offset frequency. After getting the optimal frequency offset, the sweep scans were performed using -1040 to 960 Hz with step size of 100 Hz. The mean signal intensities of the obtained sweep-scan images are displayed in Fig.3b (blue line). The iteration needed 8 loops to reach convergence and the obtained offset frequency was close to the result obtained by the sweep scan which requires 21 measurements.



a b

Fig. 3 (a) manual ROI selection on the desired region for frequency optimization. (b) the comparison of signal-time curve between sweep scan and real-time optimization. The converged MT offset frequency is -40 Hz (black vertical dash line) .

Discussion and Conclusions

This study implemented a general frame work to optimize the MT frequency for MT-related studies. The automatic method uses the same sequence as the one used in MT study. The optimization scans and the MT experiment can be combined into a single sequence execution. This system is potentially useful for APT imaging. The optimization scan serves as a pre-adjustment module to calibrate the MT frequency offset and the MT asymmetry measurement follows immediately without user-interaction. Applying real-time optimization on pulse duration or flip angle of MT preparation merits further investigations. In conclusion, the real-time frequency optimization method is a rapid and practical calibration method for MT-related study.

Reference

[1] Peng HH et al., JMRI 2009:30:596-605.

[2] Scheidegger R. et al., MRM 2011:66:1275-1285

[3] Tang YW et al., Neuroimage 2011