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In-vitro evaluation of thermal dose accuracy for high intensity focused ultrasound hyperthermia therapy: MRgFUS experience.

Fang-Chi Hsu1,2, Hsin-Lun Lee1,3, Tung-Ho Chen2, Jing-Fu Wu2, Yang-Bin Lin2, Shiu-Chen Jeng*, Jeng-Fong Chiou2

1The Ph.D. Program for Translational Medicine, College of Medical Science and Technology, Taipei Medical University and Academia Sinica, Taipei, Taiwan, 2Department of Radiation Oncology, Taipei Medical University, Taipei, Taiwan, 3Taipei Cancer Center, Taipei, Taiwan

Background/Introduction:

High intensity focused ultrasound (HIFU) has performed its non-invasive heating capability for tumour treatment. Magnetic resonance image (MRI) guided HIFU surgery has been initially proved for uterine fibroid. ExAblate MRgFUS system (Insightec, Israel) recently demonstrated hyperthermia application for malignant bone metastasis palliation and been certificated by US FDA. HIFU beam projects ultrasound power at precise local bone cortex. In order to protect nearby critical organs, thermal dose should be delivered correctly to treatment area within a short period. Over 56°C/sec heat shock theoretically creates thrombosis in human tissue. MRgFUS system embedded proton resonance frequency (PRF) algorithm to monitor real time temperatures. Hence, we reported heating calibration protocols and thermal dose, which integrates true temperature measurement and PRF readout at target spots.

Methods:

ExAblate 2000 system (Insightec, Israel) installed in Taipei Medical University and was used to treat bone metastasis for severe pain patients. This system contented a 1.5T GE magnetic resonance system and a phase array transducer with 208 independent HIFU elements. During entire evaluation processes, each sonication spot was delivered ultrasound energy (from 433J to 960J) in 20 seconds at daily quality assurance (DQA) phantom. We simultaneously used an insulated thermocouple wire (Thermoway co., Taiwan) to detect true temperature and compared with PRF temperature. Based on these data, thermal dose was calculated by Sapareto’s TD43 equivalent minutes. Statistical analysis distinguished significant differences for various sonication duration, energy, depth spot position and transducer angle. Moreover, multiple regression and Matlab models validated correlation of dose bias.

Results and Conclusions:

This report has demonstrated a further evaluation to assure temperature accuracy for MRgFUS treatment. In order to investigate the reliability of thermal dose, this method mimicked similar condition of bone cortex treatment by DQA phantom and thermal couple grid. Both PRF values and thermal couple readouts showed a consistent trend during modulating sonication energy. Sonication trend and thermal dose also showed a significant correlation by Pearson’s correlation coefficient. These results indicated that PRF image thermometry remained acceptable accuracy to endorse treatment safety. However, transducer movements created projection bias in deeper targets, which may need to be considered as a confounding factor for treatment planning. Furthermore, this method also demonstrated potentials to improve treatment accuracy and convenience.