

MAGNETIC RESONANCE THERMAL IMAGING (MRTI) DUKE EXPERIENCE WITH EXTREMITY SOFT TISSUE SARCOMAS

**Z. Vujaskovic, E.L. Jones, T.V. Samulski, L. Prosnitz, J. MacFall, O. A. Arabe,
T.E. Raidy, O. I. Craciunescu, T.Z. Wong, S. Das, N. Larrier, M.W. Dewhirst**
Dept. of Radiation Oncology and Radiology; Duke University Medical Center, Durham, NC,
USA

It is well known that a major hindrance to effective application of hyperthermia (HT) in clinical practice is the limitation of invasive thermometry techniques to characterize intra-tumoral temperature distribution. This leads to imprecise knowledge of the thermal dose-response relationship. Our recent results from two prospective randomized trials (canine soft tissue sarcomas and superficial human tumors) show that prospective control of delivered thermal dose correlates to treatment outcome. However, in spite of the overall success of these trials, the thermal dose assessments were based on invasive thermometry, which is not precise or practical for routine clinical application. The key to improved thermal dosimetry is the ability to non-invasively and accurately characterize in three dimensions intra-tumoral temperature distributions and to control these in real-time. Construction of thermal isodose contours throughout the tumor in a fashion analogous to radiotherapy dose distributions would be a major advance. The long-term goal of our research at Duke is to implement magnetic resonance thermal imaging (MRTI) to spatially monitor thermal dose distribution during hyperthermia treatment in patients with locally advanced cancers that are not effectively treated with the best conventional therapies. Our recent experience in achieving this objective in patients with extremity soft tissue sarcoma are presented, using a fully integrated MR-compatible heating system.

The method we have developed uses apparent diffusion coefficient (ADC) MR imaging to correct the proton resonance frequency shift of water (PRFS) drift. ADC imaging has very little drift, but it also provides poorer quality images due to the low signal-to-noise ratio (lower resolution images). The stability of ADC imaging can be combined with high-resolution PRFS imaging to provide drift-free, high-resolution image. We have designed, built and installed a fully integrated MRI hyperthermia treatment facility centered on a modern commercial MRI system (GE 1.5T Signa EXCITE). This exceptional facility includes novel MRI-compatible hyperthermia applicators and supporting equipment (amplifiers, filters, and control systems) specifically designed for tumors of the extremity, breast or pelvis/abdomen.

Our studies demonstrated that temperature distribution in phantoms can be measured with an accuracy of 0.3° - 0.5° C. To perform thermal treatments in patients with extremity soft tissue sarcoma, we have designed, built, and obtained an IDE for an MR-compatible mini-annular phased array applicator. The tumors were heated in MRI unit while simultaneously obtaining PRFS images during the treatment. Temperatures were also measured invasively using fiberoptic thermal probes to compare with MRTI-derived PRFS and ADC measurements. An excellent correlation was found for both phase and ADC changes as a function of temperature. The results demonstrate the feasibility for doing non-invasive thermometry and spatial control of temperature in patients with extremity sarcomas with an accuracy of 0.5° - 1° C. Furthermore, the mapping of temperature changes during the treatment based on PRFS phase difference images shows clearly that control and modulation of temperature distribution in tumor can be done in the new MRI system while making PRFS temperature difference images.

These data demonstrate our ability to perform these MRTI temperature-related measurements in a clinical setting. Further development and optimization of these method will revolutionize

our knowledge of temperatures during heating as well as allow, for the first time, implementation of intensity modulated thermal therapy (IMTT) based on the real-time control over 3-D temperature distributions. The realization of non-invasive thermometry will have additional benefits, including the ability to measure temperature distribution in sites not readily accessible to invasive catheter placement. This will allow for treatment of sites, such as the lung, brain, or pancreas not frequently treated at present because of the difficulties of catheter placement. Additionally, the hazards and discomfort of invasive catheter placement are avoided, patient compliance will improve, and physician time will be conserved. All these factors should lead to increasing acceptance of HT.