THE DESIGN OF A FULLY INTEGRATED REGIONAL HYPERTHERMIA-3T MRI SYSTEM FOR THE TREATMENT OF PELVIC TUMOURS

B. van den Bergen, C.A.T. van den Berg, L.W. Bartels, J.J.W. Lagendijk, H. Kroeze, A.A.C. de Leeuw

Department of Radiotherapy, University Medical Center Utrecht, Heidelberglaan 100, 3584 CX Utrecht, The Netherlands

Introduction

Optimal regional hyperthermia systems operate in a coherent radiative mode with the electric field along the body axis, at a frequency around 140 MHz. To allow 3D control of the focus and to ensure efficient power coupling to the patient, the gap between the antenna and the patient must be filled with a water bolus. This design has been investigated by Paulsen et al. [1] and Kroeze et al. [2] using finite difference time domain (FDTD) modeling and has been show to be the optimal design for regional hyperthermia.

Hyperthermia treatment planning can be used to find the optimal phase amplitude settings for an individual patient. However, it is essential that temperature feedback is present during treatment to guarantee the optimal settings. On line MRI may supply the actual anatomy for planning, temperature feedback and treatment response assessment. Gellerman et al. [3] used a regional hyperthermia inset system in a standard 1.5 T MRI system. Due to the different frequencies used for both systems, they could be rf decoupled and used independently.

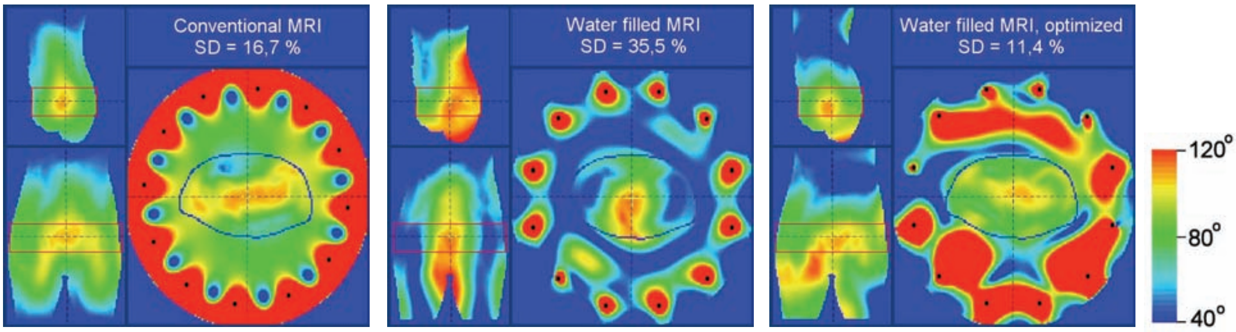
Design

The required rf frequency for regional hyperthermia is close to the Larmor frequency for a 3 Tesla MRI system (128 MHz). We propose a hybrid system in which a single 128 MHz phased array antenna is used for both excitation and regional hyperthermia. This gives the unique capability to quantify the antenna behavior in hyperthermia mode and map the actual hyperthermia fields [4]. Such a system could be built as an inset into a standard 3T clinical scanner which then would no longer use its rf body coil, or it can replace the rf body coil of a clinical scanner completely.

The benefits of the water bolus and the multiple antenna rings for hyperthermia apply equally well for imaging. I.e. the body cooling and the additional longitudinal control that supplies additional freedom in SAR and B_1^+ control for MRI [5]. The phased array capabilities of the rf antenna in a hybrid system can be used to optimize the B_1^+ homogeneity and consequently improve the image quality at 3T.

Methods and Results

To test the hyperthermia and MRI performance of the proposed hybrid system, its rf system was simulated using our hyperthermia treatment planning system [6]. A finite difference time domain (FDTD) code allows the computation of the SAR and B_1^+ distribution in realistic patients.



For comparison purposes an air based conventional 3T MR transmit coil is also simulated [5] and the results are compared with the water based hybrid system. Simulations show that the homogeneity in the 9 cm thick body cross-section that we indicated as the region of interest has a standard deviation of 35.5% and 16.7% for respectively the water filled and the conventional MRI in standard quadrature drive.

However, it is found that phase amplitude optimization can improve the standard deviation of the B_1^+ homogeneity to 11.4%. Furthermore, it is shown that the system has sufficient SAR control for hyperthermia treatment of pelvic tumours .

Conclusions

The simulations of the total system give insight into the feasibility of the hybrid MRI/hyperthermia concept. In the near future we will investigate more aspects of this design such as signal-to-noise, power amplifier requirements and the capabilities of SAR reduction for MR imaging only.

The shown hybrid system may provide heating controlled by simultaneous non-invasive thermometry. The use of 128 MHz (3T) for both applications provides a unique possibility for treatment response assessment using fMRI.

References

[1] Paulsen KD, Geimer S, Tang J, Boyse WE, Optimization of pelvic heating rate distributions with electromagnetic phased arrays. Int J. Hyperthermia, 1999, 15(3), 157-186.

[2] Kroeze H, van de Kamer JB, de Leeuw AAC, Lagendijk JJW. Regional hyperthermia applicator design using FDTD modelling, Phys Med Biol, 2001, 46(7), 1919-1935.

[3] Gellermann J, Wlodarczyk W, Feussner A, Fähling H, Nadobny J, Hildebrandt B, Felix R, Wust P, Methods and potentials of magnetic resonance imaging for monitoring radiofrequency hyperthermia in a hybrid system. Int J. Hyperthermia, 2005, 21(6), 497 – 513.

[4] Van den Berg CAT, Bartels LW, De Leeuw AAC, Lagendijk JJW, Van de Kamer JB., Experimental validation of hyperthermia SAR treatment planning using MR B_{1+} imaging. Phys Med Biol, 2004, 49 (22), 5029-5042.

[5] Van den Berg CAT, Bartels LW, van den Bergen B, Kroeze H, Lagendijk JJW, Phased array antenna concepts for high field MR, 2005, IPEM, proc. E-M Technologies (RF-THz): Applications, Safety and Human Interaction IoP Meeting.

[6] Van de Kamer JB, de Leeuw AAC, Hornsleth SN, Kroeze H, Kotte ANTJ, Lagendijk JJW. Development of a regional hyperthermia treatment planning system, Int J Hyperthermia, 2001, 17 (3), 207-220.