Perfusion Distortions and their Correction in the PRF-based Temperature Monitoring of Regional Hyperthermia

W. Wlodarczyk[1], J. Gellermann[1], J. Nadobny[1], P. Wust[1], R. Felix[1]

[1]Dept. of Radiation Medicine, Charite Medical School, Berlin, Germany

Introduction:

Simultaneous MR monitoring of three-dimensional temperature distributions in patients is a precondition for optimization of regional hyperthermia (RHT). Therefore combination of both, HT and MR hardware, was attempted and has been finally achieved in form of the first clinical simultaneously operating RHT/MR hybrid system [1]. In the next step, we developed correction procedures for MR thermography (MRTh) based on the proton resonance frequency (PRF) shifts to remove B0 drifts and B1 propagation offsets, and achieved accuracies of better than 1°C in the necrotic parts of tumors [2]. We also developed methods for MR monitoring of microcirculatory parameters and showed that in addition to the obvious thermal toxicity the vascular steal effect strongly contributes to the cancer kill in the RHT [3]. The purpose of this contribution is to confront the distributions of heat-induced PRF shifts (assigned as apparent temperature changes) and perfusion changes measured in patients under RHT in the RHT/MR hybrid system.

Methods:

MR measurements were performed at four patients with soft tissue sarcoma undergoing the therapy in the clinical RHT/MR hybrid system consisting of two simultaneously operating units: the RHT unit (BSD-2000-3D, BSD Medical Corp., Salt Lake City, UT, USA) and the MR unit (1.5 T Magnetom Symphony, Siemens Medical Systems, Erlangen, Germany) [1]. These patients had implanted catheters for uptake of temperature sensors. The RHT was applied throughout 60-70 min. Temperature monitoring was based on the PRF shifts calibrated by –0.011 ppm/°C. Multi-slice double gradient-echo sequence (TR/TE1/TE2/FA=600/4/20/50) was used to acquire 25 contiguous slices of 1 cm thickness and FOV of 50 cm. B1 propagation offsets caused by heat-induced changes of tissue conductivity and coil impedance were corrected by inter-scan differences of the B0 maps which were obtained from the intra-scan phase differences between the two echoes [2]. B0 drifts were corrected using water bolus as a reference phantom with known while sensor-measured temperature distributions. Monitoring of perfusion was performed by the dynamic contrast-enhanced MRI (DCE MRI) applying SR TurboFLASH sequence (TI/TR/TE/FA=270/500/1.2/12) every 1.5 s in 3 slices. These measurements were performed basally, i.e. 2-3 days before HT, and immediately before power turn-off of each first HT fraction. The adiabatic approximation of the tissue homogeneity model [4] was fitted pixel-by-pixel to the first-pass DCE MRI data. Maps of perfusion were confronted with the MRTh maps. Values of sensor-measured temperature in regions along the catheters were compared with the MRTh values and confronted with corresponding perfusion changes.

Results:

The PRF map acquired just before the DCE MRI measurement and the power turn-off shows pronounced temperature elevations in the necrotic part of tumor, followed by moderate and only slight elevations in muscle and at tumor rim, respectively (Fig. 1 left). The vascular steal effect of the RHT causes a redistribution of perfusion from the tumor rim to the muscle (Fig. 1 mid, right), which is followed by redistribution of susceptibility effects and so of the PRF shifts mimicking the temperature changes. The RHT-caused decrease of basally high perfusion at tumor rim lowers the PRF-extracted temperature changes (ranges 1 and 3 on Fig. 2). On the other side, the increase of basally low perfusion in healthy muscle overestimates the PRF-based MRTh (range 4 on Fig. 2). The preliminary calibration factor obtained in the four patients is 5 ml/100g/min per 1°C(PRF).

Conclusions:

Improvements of the accuracy of the PRF-based MRTh in the perfused tissue such as tumor rim and the surrounding muscle can be achieved by complementary perfusion measurements. The obtained calibration can expand the reliability of the MRTh monitoring of the RHT behind the necrotic tumor parts.

Acknowledgement: Supported by Deutsche Forschungsgemeinschaft (WL 8/1).

References: **1**. Wlodarczyk W et al., *Proc. ISMRM* 10:244 (2002); **2**. Wlodarczyk W et al., *Proc. ISMRM* 12:977 (2004); **3**. Wlodarczyk W et al., *Proc. ISMRM* 12:981 (2004); **4**. St. Lawrence KS and Lee T, *J Cereb Blood Flow Metab* 18:1365-77 (1998);

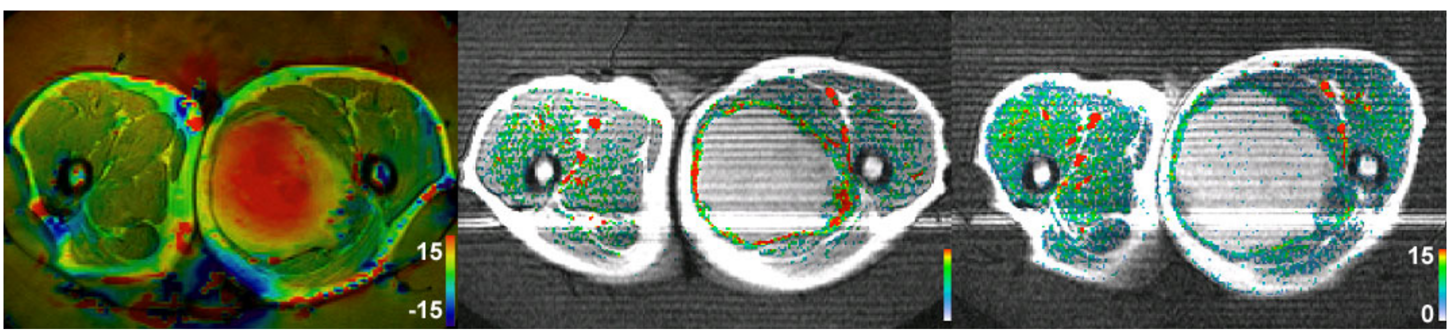

Figure 1. Map of temperature changes ΔT (scale in °C) in patient with soft tissue sarcoma in the left thigh just before power switch-off (left) and corresponding maps of perfusion (scale in ml/min/100ml) measured by DCE MRI basally before HT (mid) and just after power switch-off under the 1st HT fraction (right). Note the obvious perfusion reduction at tumor rim and perfusion increase in healthy muscle under RHT (vascular steal effect).

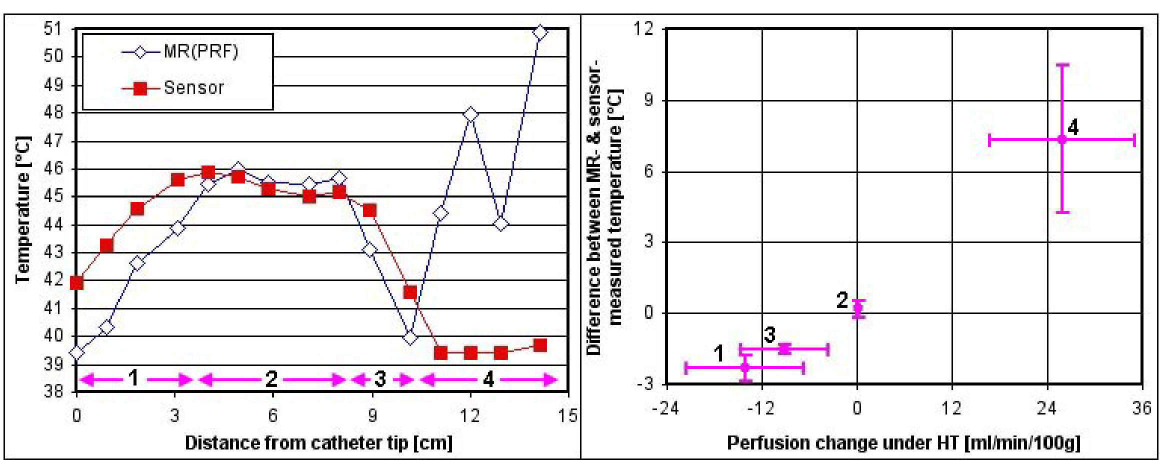

Figure 2. Temperature measured by sensor along the catheter and measured as PRF shifts (left). The catheter covers the tumor rim (1), the necrotic tumor part (2), the opposite tumor rim (3) and the subcutaneous muscle (4). The difference between the PRF- and sensor-measured temperature is a linear function of perfusion changes under RHT (right). The numbers correspond to the catheter ranges of the left diagram.