Microwave Tomography based Thermometry: a Feasibility Study

Physics: Thermometry

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MICROWAVE TOMOGRAPHY BASED THERMOMETRY: A FEASIBILITY STUDY

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Background: Temperature monitoring is crucial to achieve quality assurance and effectiveness of the treatment. It is needed both for feedback control purposes and for evaluation of the clinical efficiency of hyperthermia, by correlating the clinical outcome with the thermal dose received by the patient.
The most clinically advanced approach to non-invasive thermometry involves the use of MRI techniques, where an RF hyperthermia applicator is placed as an inset into a standard 0.5-2 Tesla clinical MRI system. This approach is however quite expensive and therefore not available to many cancer sites. In this paper investigates potentials of microwave tomography as non-invasive, inexpensive thermometry method for deep hyperthermia treatment.
Methods: The focus of this feasibility study is to determine the thermal imaging capability of the iterative electromagnetic time-domain image reconstruction algorithm and to estimate its sensitivity to temperature changes. The method was tested in several different scenarios, both numerical and laboratory experiments on tissue-equivalent phantoms. Temperature dependence of the dielectric properties of the phantom was measured by a dielectric probe and later used as a reference. The thermal imaging capabilities were then quantitatively analyzed in terms of mean, median and maximal values of reconstructed test objects.
Results: The mean and median conductivity values obtained from both synthetic and experimental data reconstructions with constant temperature background are in good agreement with those of probe measurements. Although absolute conductivity values are lower then the reference data, the slope of the conductivity increase correspond well.
The results for the permittivity reconstructions are not consistent for all the tested cases, although the permittivity is to some extent correctly reconstructed in terms of their absolute values. This can be partly attributed to changes in the temperature of the background and phantom during the experimental measurements.
Conclusions: In conclusion, we see a good agreement between the measured and reconstructed conductivity data whereas the results for the permittivity are not as easily interpreted. Both the simulated and experimental results demonstrated that the temperature estimation is possible, however, several issues remains to be solved before the method can give robust data useful in a clinical setting.

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HUMAN SERUM ALBUMIN MODULATED MRI-SIGNAL FROM GADODIAMIDE ENCAPSULATED IN THERMOSENSITIVE LIPOSOMES

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Background: Thermosensitive liposomes (TSL) are drug carriers allowing temperature triggered local drug release. If a MRI-contrast agent (CA) is encapsulated permeability of the lipid bilayer for water contributes to MRI-signal generation beside CA release. Different components in human blood such as serum albumin (HSA) are known to influence membrane stability and thus also effectiveness of drug release and its visualization.
Methods: For better understanding of release kinetics and membrane characteristics, DPPC/DSPC/DPPG2 50:20:30 (mol/mol)-TSL encapsulating either gadodiamide (Gd-TSL) or carboxyfluorescein (CF-TSL) were investigated by varying HSA content from 0 to 8g/100mL. TSL were prepared and characterized by fluorescence spectroscopy and 0.47 T-NMR-analyzer as described [1,2].
Results: Increasing HSA content in 5% glucose in the absence of Gd-TSL resulted in T1 shortening of up to 948+/-19 ms and in presence of Gd-TSL of up to 267+/-15 ms. HSA did not affect CA retention at 30°C for 40 min. Water permeability at 30°C increased linearly up to ~11% with increasing HSA content. CF release during 5 min at temperatures around and above phase transition of 42.7°C were increased with increasing HSA content but did not reach the amount released in full serum.
Conclusions: It has been shown that HSA is a major but not the solely factor influencing membrane permeability of TSL. HSA affects water permeability and thus MRI signal formation at temperatures below the phase transition of Gd-TSL without negatively influencing CA retention.

1. Peller et al. Invest Radiol 2008, 43:877-92.
2. Hossann et al. J Control Release 2010, 147:436-43.