

3-DIMENSIONAL CALCULATION OF THE TEMPERATURE DISTRIBUTION DURING THERMOTHERAPY WITH MAGNETIC NANOPARTICLES

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Thermotherapy using magnetic nanoparticles is a new cancer therapy, in which iron oxide nanoparticles are directly injected into a tumor and subsequently heated in an alternating magnetic field. The new technique has been investigated in three different clinical trials, where patients suffering from recurrences of glioblastoma, prostate and cervical carcinoma as well as a few other tumor entities have been treated.

With this method it is possible to heat tumors of 1 cm to 5 cm diameter in deep body regions. The achieved temperatures can be regulated during the therapy by changing the magnetic field strength. For the nanoparticles stay in the tumor tissue with nearly unchanged concentration for up to ten weeks, a reproducible steady state situation of temperature distribution can be chosen in every therapy session. Because of the steep temperature gradient an invasive temperature measurement can not determine the maximum temperature and neither describe the temperature distribution in the whole tumor. To overcome this problem a method for temperature calculation on basis of the bio-heat equation has been developed, which offers also the possibility predict the temperatures of changing input power.

The software Nanoplan®, on the platform Amira, allows to segment regions on basis of 3D image sets (CT, MRT, PET, Sono, ect.) and generate volumes out of them. Each volume is assigned to thermal properties as heating power (SAR), thermal conductivity and blood perfusion. The SAR of the nano particle volume (NPV) can be derived from the magnetic field strength H (actually applied during treatments), the standard heating power of the nano particles and the amount of nanoparticles (calculated out of CT density distribution) in the NPV. In an implanted thermometry catheter a 1-dimensional temperature profile (mapping) is taken during therapy after the steady state temperature is reached. The track of the catheter is reconstructed precisely in the model and the temperature profile is scaled to the measured by changing the chosen blood perfusion.

This is the basis of simulating steady state temperature distribution for changing applied magnetic field strengths. In the three trials the method has shown its reliability for predicting the tumor temperatures in comparison with measurement data of repeated sessions or multiple measurement catheter. The surface temperatures of treatments in pelvic regions are mostly underestimated. Inducted currents through the magnetic field are neglected in the used version of Nanoplan. But for the tumor area this method offers a possibility to determine temperatures with only one invasive measurement.

