Mitigation of eddy current heating during magnetic nanoparticle hyperthermia therapy

Robert Stigliano, Fridon Shubitidze, Jack Hoopes

Dartmouth College, Hanover, NH, USA

Purpose:
The purpose of this study was to develop a technique which could be employed to reduce eddy current heating of normal tissue resulting from exposure to an alternating magnetic field (AMF) during magnetic nanoparticle hyperthermia (mNPH) treatment, without decreasing mNP heating of the tumor.

Methods:
Tissue mimicking phantoms and ex vivo rabbits were exposed to an AMF of various field strengths and frequencies. The AMF was generated by a 25kW induction heating system utilizing a single turn coil with a magnetic core. Experiments were conducted using both a flat treatment table (between the coil and the phantom/animal) and using a modified table surface designed to reduce the induction of eddy currents by displacing noncancerous tissue away from zones of high electric field strength. A plastic tube containing mNP’s was embedded into the center of the phantom to evaluate the effect of the modified table surface on mNP heating above the center of the coil. Internal temperature data was collected using eight, single point fiber optic temperature sensors and surface temperature was recorded using a thermal camera. The maximum recorded rate of tissue temperature increase was used to evaluate the effect on eddy current heating in each case.

Results:
Eddy current heating was reduced by approximately a factor of two in both phantoms and ex vivo rabbits by displacing tissue by a maximum of 2.5 cm from the flat table surface. The phantom data showed that this displacement did not significantly affect mNP heating in the targeted treatment zone.

Conclusion:
Our results demonstrate the potential to decrease eddy current heating in normal tissue while maintaining mNP heating in the treatment volume by displacing normal tissue away from zones of high electric field strength. Treatments are limited by the normal tissue toxicity incurred by eddy current heating, thus, by mitigating this non-specific heating more power can be safely coupled to the coil. This has the effect of increasing the maximum treatment depth of the therapy and/or decreasing the concentration of mNP’s necessary to achieve an effective thermal dose, which is a major stepping stone toward the treatment of metastatic cancer.