Experimentally verified time-dependent thermal model for the development of optimal local ultrasound hyperthermia

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A thermal model has been developed for predicting time-dependent temperature distributions during ultrasound hyperthermia. Relevant thermal processes incorporated in the model are heat conduction and ultrasound power absorption. An experimentally verified ultrasound beam model and experimentally derived conversion factor were used to compute the absolute ultrasound intensity distribution. The thermal model is a parabolic partial differential equation and was solved numerically by a finite difference method--the Alternating Direction Implicit method.

A tissue-mimicking phantom, along with a computer controlled temperature monitoring system, was assembled for testing the thermal model. The entire assembly was used to determine time-dependent temperature changes at various points in the phantom in response to the application of a focused, continuous wave ultrasound beam at 525 KHz. All relevant ultrasonic and thermodynamic properties of the tissue-mimicking material were accurately measured for use in the thermal model.

Time-dependent temperature changes predicted with the thermal model agreed very well with those found experimentally. This agreement verifies the validity of the model so that heating predictions made without repeated experimental verification--and using various applicator geometries--have credibility. Thus, applicator geometries can be optimized by computer modelling for specific treatment situations.

A rotated dual-element focused applicator is proposed for optimal local ultrasound hyperthermia. This applicator has a variable configuration which can be tailored to a given tumor's dimensions. A time-averaged intensity distribution was used for calculation of the time-dependent temperature distributions assuming the rate of rotation is sufficiently higher than all the rates of relevant thermal processes. A three-dimensional numerical algorithm was implemented to determine the rotational velocity at which time-averaged intensity applies and to study the magnitude of temperature fluctuations at various rates of rotation.

A prototype phantom has been developed for quality assurance of ultrasound hyperthermia systems. The phantom is capable of evaluating intensity distribution and time-dependent temperature distributions. It is essential for developing quality assurance protocols to guarantee safe and reproducible patient treatment.

Convective energy transfer by blood perfusion was not mimicked in the phantom for this thesis research. Thus, the predictive ability of the thermal model remains to be tested in this regard.