

NUMERICAL FEM MODELS FOR THE PREDICTION OF TEMPERATURE DURING SUPERFICIAL MW HYPERTHERMIA TREATMENTS

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Introduction. There are different approaches for microwave hyperthermia treatments. Local applicators allow superficial treatment of tumours that is effective and non-harmful, with minimal side effects and improved patient comfort. Thermal distribution in the target area depends not only on the power applied and the exposure time, but is also closely correlated with tissue blood perfusion [1], dielectric properties [2] and tissue-to-applicator matching [3]. It is important to take all these factors into account when planning treatment. Various numerical models will be presented and discussed.

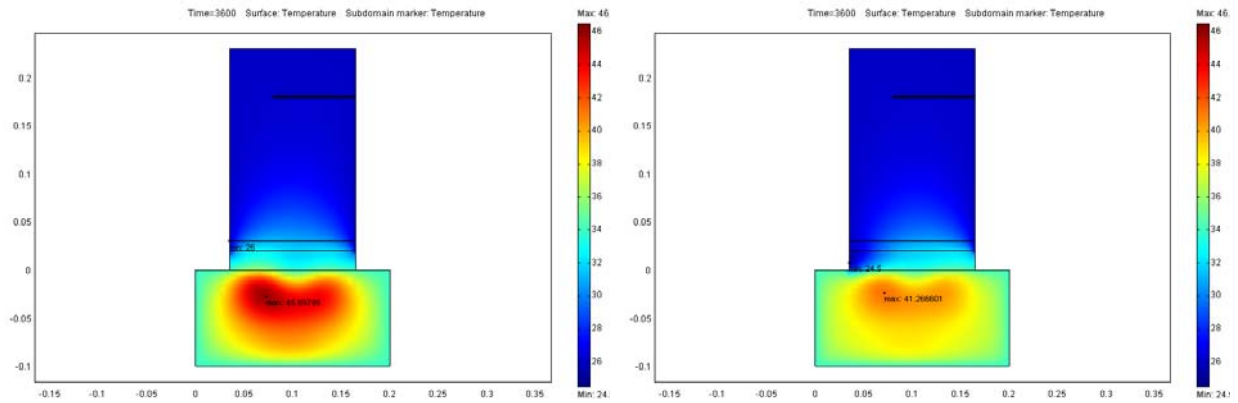
Methods. Some simple numerical models of a local microwave applicator operating at 915 MHz (MA-100, BSD Medical Corp., Salt Lake City, UT, USA) were developed and solved to evaluate temperature distribution after 60- and 90-minute transients. The MW-power applied was initially set to a fixed value; a parametric study was performed to evaluate the effect of different power levels. Different vessel positions within the tissue were studied. A finite-element code was used to solve coupled electromagnetic and thermal problems with material characteristics dependent on temperature. We started with simple models, then added more details and compared the results.

Results. The penetration depth is in a good agreement with the typical clinical range. At 100 W, the tissue temperature ranges from 41 to 46 °C, depending on the model. The tissue blood perfusion [1] does have a strong effect on the overall temperature distribution, bringing a diffuse cooling effect (Figg.1-2). The water inside the bolus can be kept still or flowing; however, when water flow is taken into account, conduction continues to be the predominant aspect in tissue-to-water thermal exchange, as convection does not introduce clear differences compared to conduction only. The presence of a larger blood vessel near the treatment zone produces a local sink effect, thus introducing hot spots which make the heating less homogeneous and lower the overall treatment effectiveness (Fig.2). When temperature-dependent tissue dielectric properties are taken into account [2], we obtain a thinner and much hotter deposition pattern, even at lower power levels. A study on the optimal power level for each situation was then performed in the course of a time-dependent parametric analysis (Fig.3).

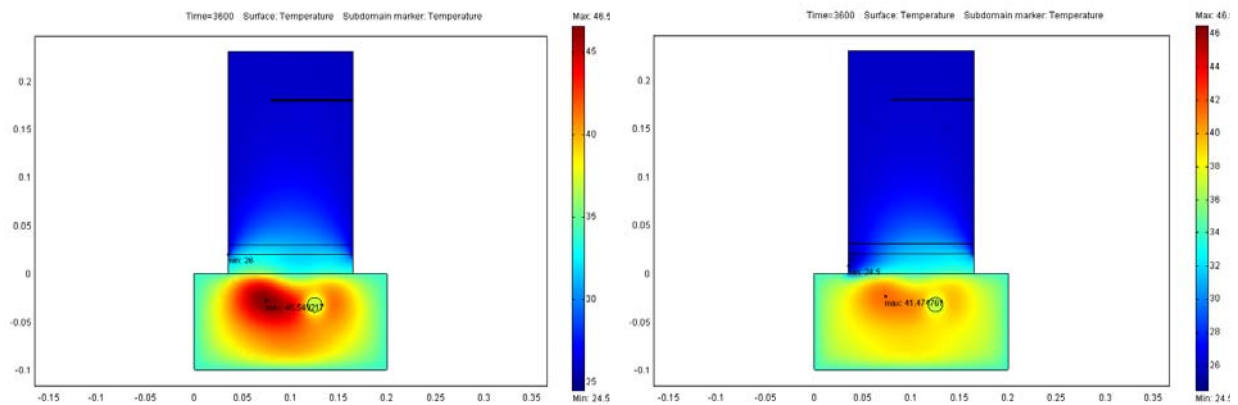
Conclusions. Local hyperthermia effectiveness is highly dependent on the temperature distribution in the tissue and on the temperature of the circulating water bolus. This is in turn influenced by tissue properties and vascularisation, which in their turn again depend on temperature. The numerical models presented attempt to describe these phenomena but further investigations are necessary to validate them in clinical application.

References.

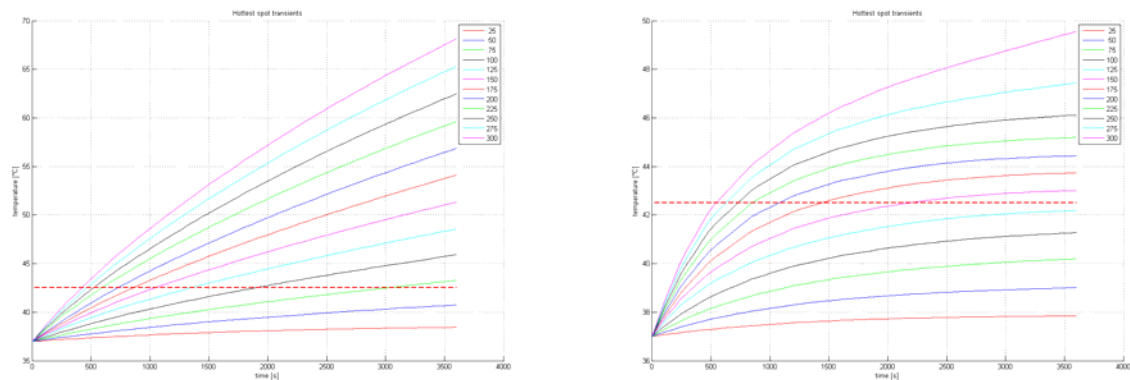
- [1] J. Lang et al., "Impact of nonlinear heat transfer on temperature control in regional hyperthermia", *IEEE Trans. Biom. Eng.*, vol.46, n.9, pp.1129-1138, 1999
- [2] L. Chin, M. Sherar, "Changes in dielectric properties of ex vivo bovine liver at 915 MHz during heating", *Phys. Med. Biol.*, vol.46, pp.197-211, 2001
- [3] M. Puchinger et al., "Heat transport trough the bolus membrane of a local HT-applicator", *19th Annual Meeting of the European Society for Hyperthermic Oncology (ESHO 2001)*, Verona (Italy), May 30 - June 2, 2001



A) without tissue blood perfusion B) with blood perfusion and water convection
Fig.1 – Thermal deposition on fatty tissue and hot spot marker; power applied: 100 W; treatment time: 60 minutes.



A) without tissue blood perfusion B) with blood perfusion and water convection
Fig.2 – Thermal deposition on fatty tissue with \varnothing 1.5 cm blood vessel and hot spot marker; power applied: 100 W; treatment time: 60 minutes.



A) without tissue blood perfusion B) with blood perfusion and water convection
Fig.3 – Hot spot temperature transients for various power levels (25÷300 W) and target tissue temperature (42.5 °C) in red dashed line; treatment time: 60 minutes.