

NUMERICAL MODEL FOR RF CAPACITIVE HYPERTHERMIA FOR BRAIN TUMOURS

V. D'Ambrosio¹, F. Dughiero¹, M. Giri², S. Maluta²

¹ Electrical Engineering Department, University of Padua, Italy

² Radiotherapy Department, University-Hospital of Verona, Italy

e-mail: fabrizio.dughiero@unipd.it

Introduction

The survival time of patients with malignant brain tumours is low due to very frequent local recurrences. Radiofrequency capacitive hyperthermia, at 13.56 MHz, can be used as an adjuvant treatment of the traditional radiotherapy and chemotherapy for advanced inoperable malignant brain tumours. Some clinical studies have demonstrated the efficacy of thermal treatment to delay the tumour growth [1]-[6].

Thermal treatment should provide the reaching of therapeutic temperature in the entire tumour and its surroundings, avoiding thermal damage to the functionally important healthy brain tissues. Temperature can be controlled with a small number of implanted probes, but this way seems to be excessively invasive and in contrast with the choice of non-invasive capacitively coupled hyperthermia.

The proposed treatment planning method is based on numerical simulations that predict the temperature distribution on 3D geometric model derived from CT or MR images of the patient.

Method

The anatomical model of the patient brain is obtained from a CT data set of a patient with a glioblastoma. The mesh has been obtained using the Amira package (Amira-TGS). The dielectric and thermal properties of tissues have been derived from literature [7] and shown in Table I.

Table I.
Electric and thermal properties used for the calculations

	σ	ϵ	k	ρ	c	F
Bolus	0.5	80	6	1000	4180	0.0
Bone	0.028	10	0.44	1800	1300	0.13
Gray matter	0.4	280	0.6	1020	3500	7.01
White matter	0.3	170	0.6	1020	3500	2.00
Tumor	0.25	130	0.6	1020	3500	4.34
Cerebrospinal fluid	0.95	80	0.6	1020	3500	0.0

As the wavelength of the RF electromagnetic field in tissues is much greater than the depth of the treated region, the quasi-static electric field approximation can be applied solving the Laplace equation to describe the electric power density distribution in the brain. To describe the evolution of temperature in human tissues the bio-heat transfer equation (BHTE) formulated by Pennes [8] has been used:

$$\rho c \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + \sigma E^2 - c_b W_b (T - T_b) \quad (1)$$

where E is the rms value of the electric field, calculated solving the electric conduction problem; ρ is density [kg/m^3]; c is specific heat [J/kg K]; k is thermal conductivity [W/m K]; T is temperature [K]; c_b is specific heat of blood [J/kg K]; and W_b is blood mass flow rate [kg/s m^3] and T_b temperature of blood [K].

The electric field and temperature distribution are computed using a FEM code. The electrodes voltages were chosen to obtain a total absorbed power of about 100 W. The heating time was set at 2100 sec, the temperature of bolus bags at the constant value of 10°C and the ambient air at 22°C .

Conclusions

Result of electric potential distribution obtained during a capacitive hyperthermia treatment is shown in fig.1.

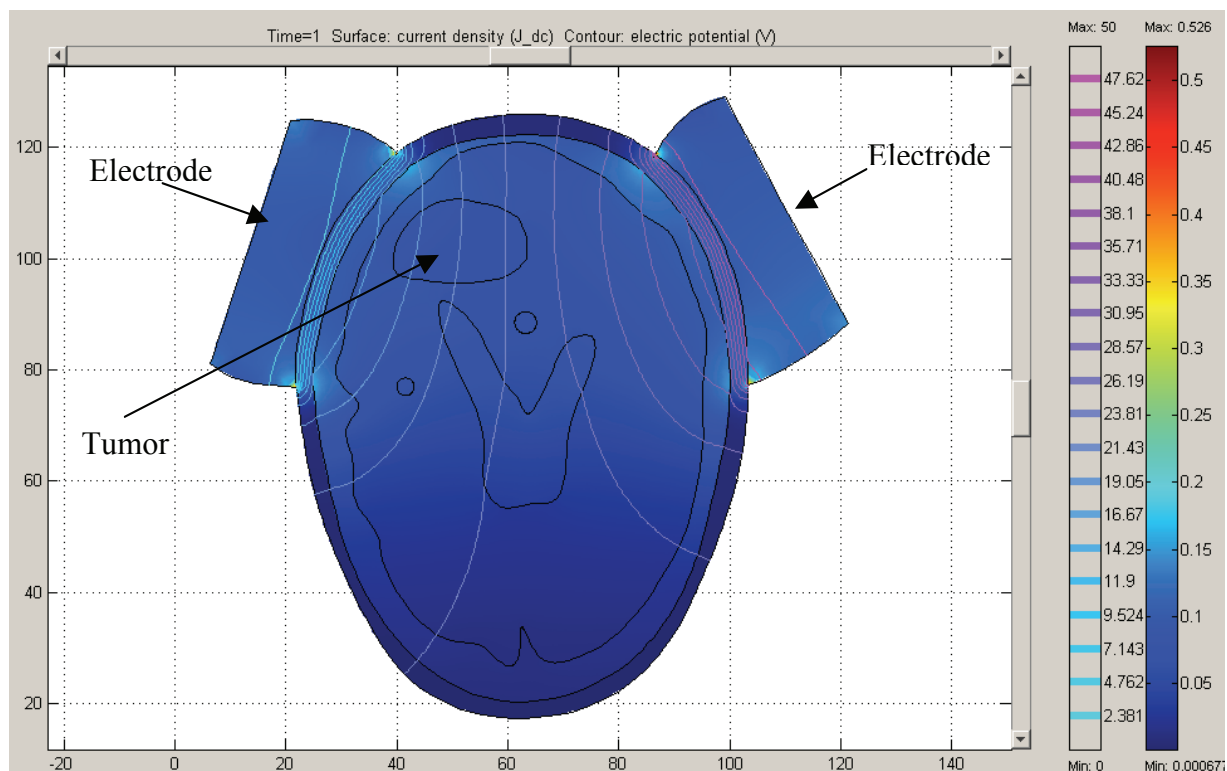


Figure 1: Electric potential (as contour) and current density (as colormap) distribution.

Some other electric and thermal results will be presented. The proposed treatment planning based on FEM simulation could represent a valid method to investigate the efficiency of the thermal treatment and the most suitable devices.

References:

- [1] Roberts DW, Coughlin CT, Wong TZ, Fratkin JD, Douple EB, Strohhahn JW. Interstitial hyperthermia and iridium brachytherapy in the treatment of malignant gliomas: a phase I clinical trial. *J Neurosurg* 1986; 64: 581± 7.
- [2] Guthkelch AN, Carter LP, Cassady JR, Hynynen KH, Iacono RP, Johnson PC, Obbens EAMT, Roemer RB, Seeger JF, Shimm DS, Stea B. Treatment of malignant brain tumors with focused ultrasound hyperthermia and radiation: results of a phase I trial. *J. Neuro-Oncol* 1991; 10: 271± 84.
- [3] Sneed PK, StauOEer PR, Gutin PH, Phillips TL, Suen S, Weaver KA, Lamb SA, Ham B, Prados MD, Larson DA, Wara WM. Interstitial irradiation and hyperthermia for the treatment of recurrent malignant brain tumors. *Neurosurg* 1991; 28: 206± 15.

- [4] Sneed PK, Gutin PH, StauOEer PR, Phillips TL, Prados MD, Weaver KA, Suen S, Lamb SA, Ham B, Ahn DK, Lamborn K, Larson DA, Wara WM. Thermoradiotherapy of recurrent malignant brain tumors. *Int J Radiation Oncol Biol Phys* 1992; 23: 853± 61.
- [5] Stea B, Rossman K, Kittelson J, Shetter A, Hamilton A, Cassady JR. Interstitial irradiation versus interstitial thermoradiotherapy for supratentorial malignant gliomas: a comparative survival analysis. *Int J Radiation Oncol Biol Phys* 1994; 30: 591± 600.
- [6] Sneed PK, StauOEer PR, McDermott MW, Diederich CJ, Lamborn KR, Prados MD, Chang S, Weaver KA, Spry L, Malec MK, Lamb SA, Voss B, Davis RL, Wara WM, Larson DA, Phillips TL, Gutin PH. Survival benefit of hyperthermia in a prospective randomized trial of brachytherapy boost +/- hyperthermia for glioblastoma multiforme. *Int J Radiation Oncol Biol Phys* 1998; 40: 287± 95.
- [7] <http://niremf.ifac.cnr.it/cgi-bin/tissprop/htmlclie/uniquery>
- [8] Pennes HH. Analysis of tissue and arterial blood temperatures in the resting human forearm. *Journal. Applied. Physiology*. 1948, vol. 1, 93-122