Ferromagnetic nanoparticles dose based on tumor size in MFH cancer therapy

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I. Introduction

One of the focal points that have not yet been clarified for MFH is how to generate a therapeutical temperature of at least 42^0C inside the tumor [1]-[2]. A computational model was created by using COMSOL: Multiphysics, in order to analyze the heat dissipation within the tumor tissue for various concentrations of magnetic nanoparticles considered in their hysteretic and superparamagnetic behavior. There were taking into account the physical and physiological properties of different tissues (breast, liver and skin tissues).

II. Computational simulations

In accordance with the biocompatibility criterion of exposure proposed by Hergt [1], when considered particles of magnetite of 18 nm diameter in their superparamagnetic behavior, the loss power should be less than 6×10^9 W/m^3, values that correspond to the amplitude of the external alternating electromagnetic less than 10 kA/m and the field frequency less than 250 kHz, we designed simulations of a spherical tumor with a volume of 1.2 – 3.5 cm^3 located in a cubical region within the tissue. A systematically variation in tumor diameter and particle dosage for every physical parameters of tumor tissues was performed in order to understand the interdependency of these parameters and their effects on MHF therapy.

In the first two models the magnetic nanoparticles were concentrated in small regions homogenously distributed around the tumor border. The amount of magnetite material required to produce the optimum temperature was varied from 3 up to 12 mg in each cm^3 of tumor tissue. Also we assumed the presence of several blood vessels near the tumor region in order to study the influence of constant systemic blood temperature on the heat dissipation into the tissues. In the first simulation, the spherical tumor was located into a tissue region approximated by a cubical space of 3.5 cm diameter, at 7.5 mm distance from two blood vessels of 0.5 mm and 1.2 mm diameter respectively. The tumor dimension was systematically varied from 1 to 1.6 cm. In the second model, we assumed the presence of one more blood vessel at 1 - 2 mm distance from the tumor border. In the third model the particles were randomly concentrated in 6 regions of 0.9 mm diameter inside the tumor region of a volume of 1 cm^3 from the breast tissue for a concentration of nanoparticles ranging between 6 – 13 mg/cm^3.

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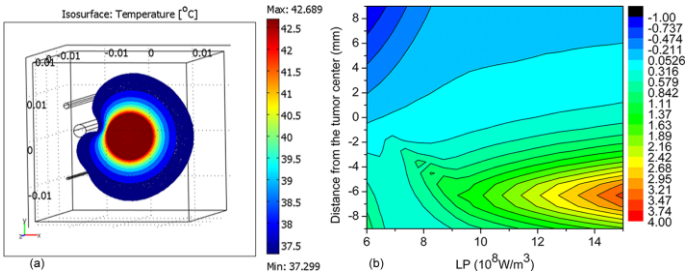

Fig.1. (a) Spatial temperature distribution in liver tumor for LP = 1×10^9 W/m^{3}and concentration of nanoparticles of 5 mg/cm^3 – second model described.
(b) The temperature differences (^{0}C) in the breast tissue when computing the first two models for a concentration of nanoparticles of 8 mg/cm^3.

III. Results

We compared the results achieved from the first two models and we concluded that in the case of liver and breast tissue the presence of a blood vessel near to the tumor has an increased influence on the heat dissipation (Fig.1), farther blood vessels having only a slight influence on the heat dissipation. In Fig.1b the negative axis corresponds to the tissue region next to the blood vessel of 2.8 mm diameter. When increasing the tumor diameter from 1 up to 1.6 cm, we observed that in the same conditions (LP) the tumor border temperature achieved does not change noticeably, but the variation of the field features (amplitude and frequency) and the concentration of nanoparticles values lead to a larger increase in tissue temperature than with smaller tumors. In the third simulation conducted on breast tissue, the tumor diameter was varied from 2.7 up to 3.4 mm for different concentrations of nanoparticles (6, 10, 13 mg/cm^3). Small temperature variations may be achieved when the tumor diameter is increased for values of LP less than $(4.5 - 5) \times 10^9$ W/m^3.

IV. Conclusions

In conclusion, by using these models and if the tumor shape and position are known from suitable medical imaging techniques (e.g. MRI, CT), it is possible to estimate the impact of the particle dose on the efficiency of hyperthermia therapy, taking also into account the local features and external factors involved.

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References

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