3D Simulation of Laser Interstitial Thermal Therapy in the Treatment of Brain Tumors

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Abstract

Abstract: Due to the restriction of the number of probes that a patient can tolerate, and the inaccurate information provided by the invasive temperature measurements, which provide information only at discrete points, a mathematical model simulation is more effective to help doctors in planning their thermal treatment doses. This will maximize therapeutic effects while minimizing side effects. Such a simulation will indicate prior to the treatment a precise idea of the predicted reaction depending on selected doses; so new treatment strategies can be proposed and evaluated.

The objective of this study is to simulate the Laser interstitial thermal therapy in treatment (LITT) of brain tumors. The thermal effect of the laser during coagulation lasts around one second and its temperature is between 50 and 90C. LITT has the following results; the desiccation and retraction of the tissue to destroy tumor phenomena. Using the laser energy source, light is emitted from a diffusive tip of an optical fiber probe that is inserted into the center of a brain tumor.

COMSOL Multiphysics® software will be used to simulate the mathematical model which includes thermal conduction (based on either Fourier's law or modified Fourier's law), constant blood perfusion and evaporation as a boundary condition. The Heat Transfer Module will be used with material library models for brain and probe solid materials. Two new Brain materials (one healthy and the other with tumors) will be defined with their density, conductivity, specific heat, diffusivity, relative permittivity, relative permeability and electrical conductivity values. A new material laser delivery probe will also be defined as source energy.

Expected results are thermal distribution through the biological tissues during the heating and temperature distribution inside the biological tissues. We will also compare thermal conduction results on either Fourier's law vs. modified Fourier's law. An expected result is the estimation of the volume of tissues damaged during the treatment.

Furthermore predicting the result of the laser interstitial thermal therapy in treatment of brain cancer depending on scenarios discussed between doctors and patients will improve the health care system by providing a personalized and focused treatment.

Using COMSOL software, we will build apps for doctors' use. Our COMSOL Multiphysics

model will be turned into an application with its own interface using the tools provided with the Application Builder desktop environment. Doctors will use their laptops or smart phones to access and run the application remotely.

Reference

1. M.M. Tung, M. Trujillo, J.A. Lopez Molina, M.J. Rivera, E.J. Berjano, Modeling the Heating of Biological Tissue based on the Hyperbolic Heat Transfer Equation, Universidad Politecnica de Valencia, Valencia, Spain. Physics.med-ph, 20 Nov 2008.

2. A.M. Mohammadi and J. L. Schroeder, Laser Interstitial thermal therapy in treatment of brain tumors – the NeuroBlate System, 2014, Informa, UK Ltd.

3. R. Tyc, K.J. Wilson, Laser Surgery/Cancer Treatment: Real-time interactivity enhances interstitial brain tumor therapy, BioOptics World, 05/2010.

4. X. Chen, G.M. Saidel, Modeling of Laser Coagulation of Tissue with MRI Temperature Monitoring, Journal of Biomechanical Engeneering, 2010.

5. Introduction to COMSOL Multiphysics 5.0, COMSOL Documentation

6. Introduction to Application Builder, COMSOL Documentation

Figures used in the abstract

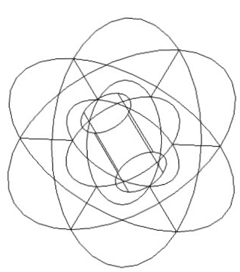

Figure 1: LDP (cylinder) and two brain tissues (spheres).

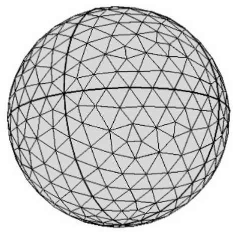

Figure 2: Mesh of the model in the COMSOL software.

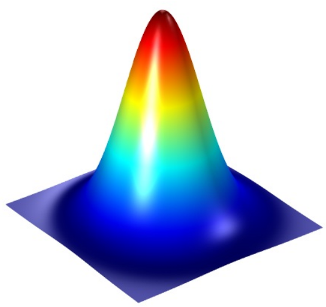

Figure 3: Analytic results.

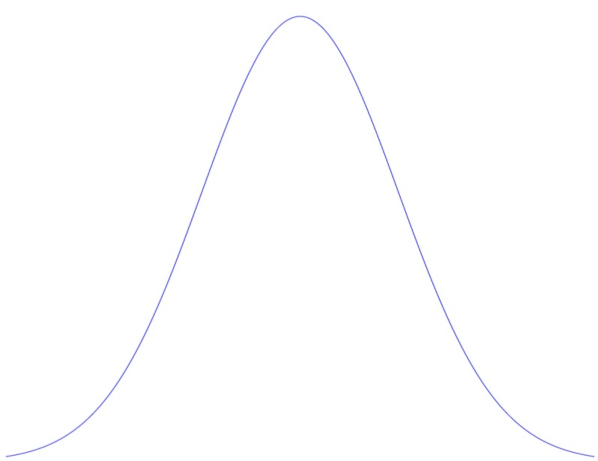

Figure 4: Results showing a Gaussian pulse.