A model to simulate laser ablation in vascularized tumor based on dynamic photothermal coupling interaction

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Introduction:

- In laser immunotherapy, the photothermal effect induces immune responses by destroying and interrupting tumor cells through temperature elevation in target tissue.
- Tumor is rich in vasculartur, and plays a critical part in photothermal effect.
- We focus on the effect of the large vessel around tumor and the mircovessel in tumore on photothermal therapy.

Computational Methods:

- Photon propagation from laser light was described by diffusion approximation:

$$\frac{n}{c}\frac{\partial\varphi(x,y,z,t)}{\partial t}+\nabla\cdot(-D\nabla\varphi(x,y,z,t))+u_a\times\varphi(x,y,z,t)=Q(x,y,z,t), \quad (1)$$

- The bioheat equation is the realizing of the principle of conservation of the energy applied to tissue volume:

$$\rho C_p\frac{\partial T}{\partial t}+\rho C_p\mathbf{u}\cdot\nabla T+\nabla\cdot\mathbf{q}=Q+Q_{bio}$$

$$Q_{bio}=\rho_b C_{p,b}\omega_b(T_b-T)+Q_{met}$$

- 3D base model of liver tissue consist of a cube of 10*10*10cm^3 with the central in point(0mm,0mm,0mm) shown in Fig.1. The cube contains a tumor with a diameter 20mm and a blood vessel approximated by the cylindrical shape.

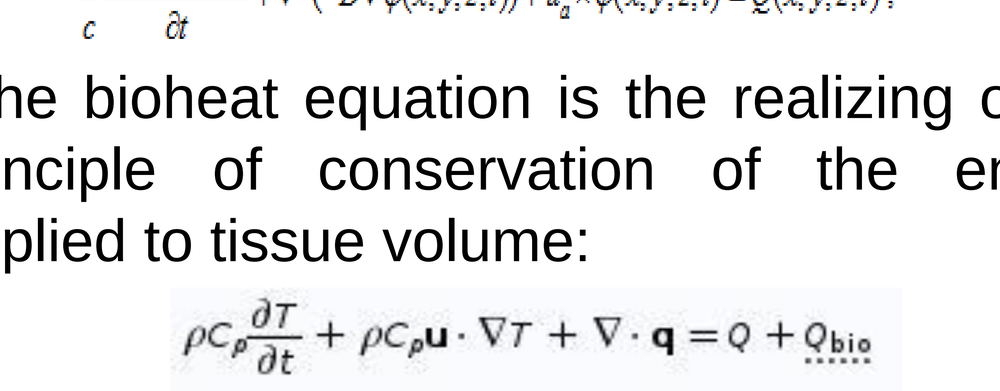

Figure 1. Tissue model

Results:

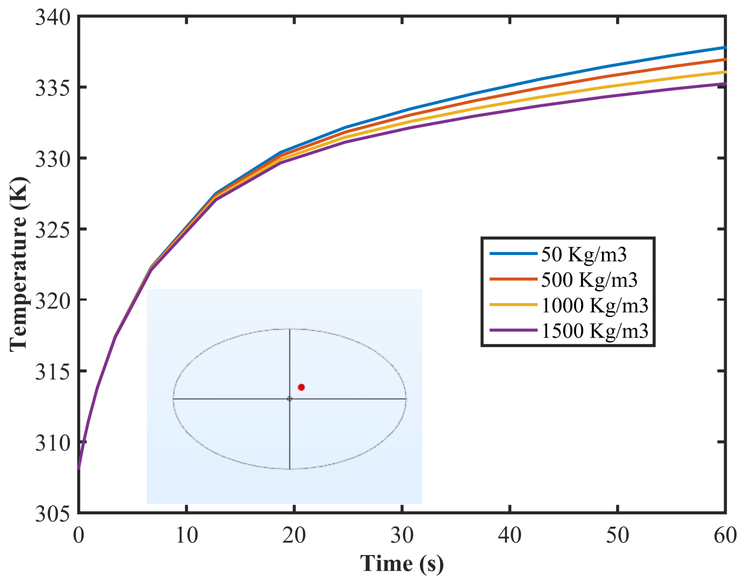

Figure 2. Temperature at point (0 0.05 0.05) vs time at the different blood densities

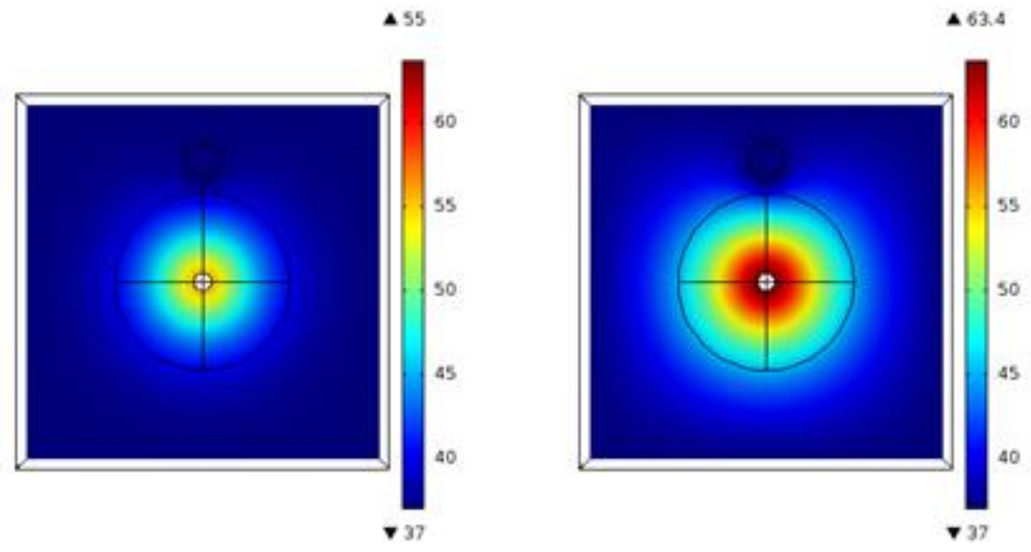

Figure 3. Cross-section images of the temperature distribution varying with irradiation time of (a) 150s; (b) 600s. The white parts denote light sources, big black circles are tumor regions, the small circles are blood vessels.

Conclusions:

Vascularized tumour grown within in a vascularized tissue displays a characteristic compartmentalization into essentially three regions: highly vascularized tumour, well-vascularized tumour and poorly vascularized tumour. These region could be described by blood density. Furthermore, the large blood vessel has the cooling effect. Finally, we should consider the sizes of tumor and light beam.