NUMERICAL STUDY OF BLOOD PERFUSION RATE IN HUMAN TUMORS UNDER LASER IRRADIATION

Ying He*, Minoru Shirazaki*, Hao Liu**, Ryutaro Himeno*, and Zhigang Sun***

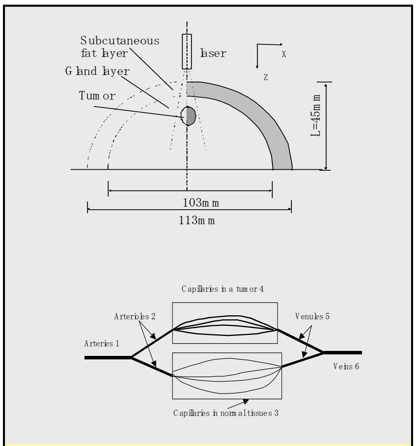
*Computational Biomechanics Unit, RIKEN, 2-1 Hirosawa, Wako-shi, 351-0198, Japan
** Faculty of Engineering, Chiba University, 1-33 Yayoi-cho, Inage-ku,
*** ASTOM R & D, RIKEN, 2-1 Hirosawa, Wako-shi, 351-0198, Japan

Research Background

- The vascular effect of hyperthermia is of much interest because of its prospective application in a combined thermo/radiotherapy or thermo/chemotherapy
- Modeling the hyperthermia-tissue-blood flow interaction is benefit for the analysis and optimization of the parameters governing planned tumor treatment procedures

Objective of the Study

- Investigate the variation of blood perfusion rate in a human breast with a tumor under laser irradiation and its effect on the oxygen distribution in the normal and tumor tissue



Laser irradiated breast model and the blood circulation network

Analysis models

- One-dimensional non-linear model of pulsatile flow -- analysis of blood flow in different vessels
- FE (finite element) thermal model -- analysis of temperature distribution in a human breast with a tumor
- The Krogh tissue cylinder model -- analysis of oxygen transport in a normal tissue unit and tumor unit

Governing Equations

Blood flow:

$$\frac{\partial A}{\partial t}+\frac{\partial q}{\partial x}=0$$

$$\frac{\partial q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{q^2}{A}\right)+\frac{A}{\rho}\frac{\partial P}{\partial x}=-\frac{2\pi \nu r}{\delta}\frac{q}{A}$$

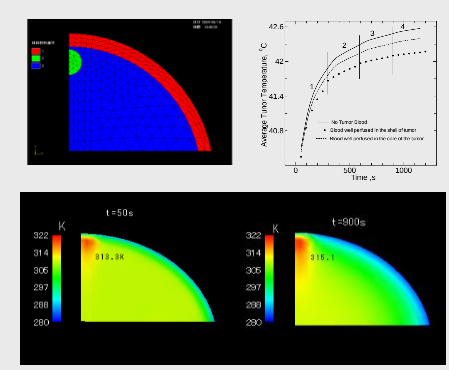
$$\frac{\partial T_b}{\partial t}+\frac{q}{A}\frac{\partial T_b}{\partial x}=-\omega T_b-\frac{h_{ves}A_s}{\rho_b c_b A}(T_b-T_t)$$

Temperature distribution in the tissue:

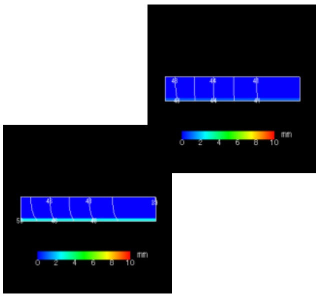
$$\rho_t c_t\frac{\partial T_t}{\partial t}=\lambda_t\left(\frac{\partial^2 T}{\partial^2 r}+\frac{1}{r}\frac{\partial T}{\partial r}+\frac{\partial^2 T}{\partial^2 z}\right)+Q+\omega\rho_b c_b(T_b-T_t)$$

Oxygen distribution:

$$\alpha\frac{\partial PO_2}{\partial t}+u\alpha\frac{\partial PO_2}{\partial x}=D_{eff}\alpha\left(\frac{\partial^2 PO_2}{\partial x^2}+\frac{\partial^2 PO_2}{\partial y^2}\right)-M$$

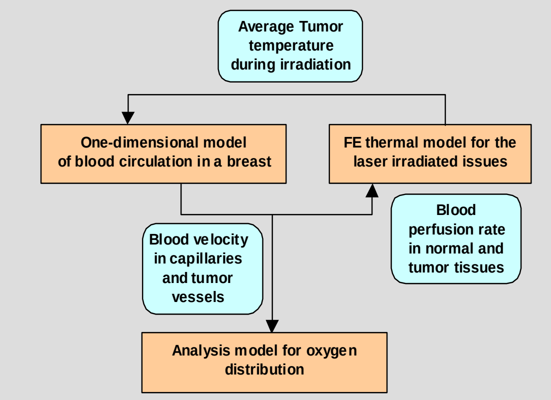


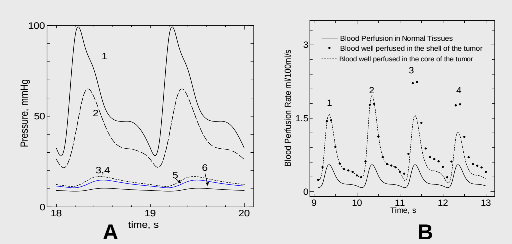
FE model and temperatures in the laser irradiated issue



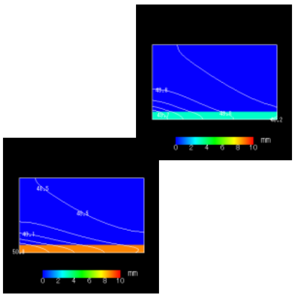
Oxygen distribution in a normal tissue unit

The coupling method between the analysis models





A) Blood pressure in different vessels
B) Blood perfusion in the normal tissue and tumor tissue



Oxygen distribution in a tumor tissue unit