

Effects of Nonideality in Vascular Network Response on Heat Transfer in Living Tissue

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Hyperthermia treatment of tumors and thermal therapy techniques based on the laser light absorption require rigorous control over the tissue temperature inside the tumor as well as the normal tissue. So mathematical modeling of heat transfer in living tissue can be important for optimizing such treatments. Heat transfer in living tissue is mainly governed by three factors: heat generation, for example, due to laser light absorption, heat diffusion through the cellular tissue, and effective heat withdrawal caused by blood perfusion. The last factor is characterized by the rate of blood perfusion through a given region of living tissue. Its value is strongly affected by the tissue response to local heating. Locally the blood perfusion rate can exhibit a tenfold increase when the temperature comes close to the upper boundary of the survival interval about 42-45 C. This increase is due to the expansion of not only small arterioles but practically all the vessels making up the corresponding peripheral bed. Therefore the temperature growth at one point of living tissue should give rise to the perfusion increase at other points. This effect becomes essential under local strong heating. In order to describe the tissue response to strong heating I.A. Lubashevsky and V.V. Gafiychuk [1] have proposed a cooperative mechanism of tissue self-regulation. It is based on the information self-processing caused by the hierarchically organized vascular network together with mass- and heat-conservation. It was shown that for the ideal dependence of the vessel expansion on the blood temperature the tissue response is perfect, i.e. the perfusion rate is determined by the tissue temperature at the same point only. For the real dependence of the vessel expansion on the temperature this property is broken down and the blood perfusion is determined by the tissue temperature inside a certain region. The present work studies this nonlocal effect depending on the properties of the vessel expansion as well as the other effects of the non-ideality in the living tissue response and analyzes the characteristic features of heat propagation in living tissue under different conditions.

[1] I.A. Lubashevsky and V.V. Gafiychuk, Cooperative mechanism of self-regulation in hierarchical living systems, SIAM, J. Appl. Math. 60, 633 (2000).