Control Problems of Refractive Index of Immersion Liquids in Imaging of Biological Tissues

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Abstract: One of the important directions in modern biomedical diagnostics is the development of methods aimed at improving the visualisation quality of the biotissue structure. The main problem of the optical tomography is related to the peculiarities of the light propagation in biological tissues: the light field propagated through an object is characterised by a significant predominance of the multiply scattered component over the unscattered (ballistic) component. Quite often, it is the latter component that is the carrier of useful information in the visualisation of the internal structure of the medium. This problem can be solved by increasing the penetration depth of ballistic photons in the object under study. To do this, the solutions of glucose, glycerine, and other immersion liquids are applied on the skin surface. The liquid diffusion into the tissue depth leads to equalization of the refractive indices of the main tissue and the scatterers, which results in a controlled decrease in the scattering coefficient and an increase in the ballistic components in a propagating signal.

Usually, due to the presence of the epidermal barrier, the penetration depth of the immersion liquid does not exceed 150–250 mm. This depth can be increased with the help of intracutaneous injections of a solution, which is localised for some time in the tissues of a patient. Despite the fact that from the medical point of view the use of the cutaneous introduction of the agent is more preferable, the efficiency of the optical immersion is significantly higher in the case of the intracutaneous injection.

There is an opinion that the best visualisation quality of the medium under study is achieved in the case of complete equalization of the refractive indices of the basic substance and scatterers, leading to the disappearance of scattering. Indeed, in most cases, this statement is justified because it is confirmed by numerical simulations and physical experiments. However, much depends on the formulation of the problem, the choice of the diagnostic methods, the medium structure and its characteristics.

We study analytically and numerically the control problems of optical properties of biological tissues in order to increase the tomographic contrast of the medium. Control problems was seen as an extremum problem for the radiation transfer equation with generalized conjugation conditions at the interface. It is shown that the complete equalization of the refractive indices does not always lead to an increase of that fraction of the ballistic component of the measured signal, which is caused by the presence of a foreign inclusion in the medium.

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