Light-tissue Interaction Modeling Using COMSOL Multiphysics® for Multi-layered Soft Tissues

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Abstract

Soft tissues are longest tissue structures found throughout a human body. It plays a vital role in connecting, providing support or surround other structures and organs of the body. Muscles, skin, tendons, ligaments, nerves, fibrous tissues, fat, blood vessels are commonly classified as soft tissues. Diagnosis of soft tissue abnormalities normally follow invasive tissue biopsy / blood analysis. Diffuse optical methods provide immense opportunity for evaluating and assessing the extent of the disease in comparison with normal tissue and also is a typical non-invasive alternative to conventional biopsy. Diffuse Optical Spectroscopy (DOS) generally employs the reflected or transmitted light between multiple source-detector pairs on the tissue surface to reconstruct the distributions of the optical properties or their variations inside an object, and then relates these physical parameters to a physiological or pathological status in biological tissue. The diffusion equation is used for studying the migration of light through tissues. Solving the diffusion equation analytically is computationally costly and is tedious. In earlier works, Monte Carlo simulations were made used for determining the fluence. But studies have shown that COMSOL® is a more powerful tool for producing more accurate and faster computation than standard Monte Carlo method of light transport in tissues. So a numerical simulation study in this direction was carried out using software COMSOL Multiphysics® for determining fluence.

In this work, we have modeled a multi-layered skin tissue in COMSOL® and studied the effect of light in tissue using a near infra-red source. Helmholtz equation module in COMSOL Multiphysics® was used to simulate light propagation studies since it is equivalent to the diffusion equation. A rectangular block with optical properties of normal human skin for different skin layers was assigned and the related physics was allocated for each of these layers. Partial flux boundary condition was applied to these layers and the fluence along the skin surface was analyzed. The 2D line plots showed the distribution of light fluence at each of these layers and the depth from which maximum or change in intensity can be obtained. So this model can be used for analyzing the extent of cancerous affected sites from normal skin and also helps in determining the magnitude of progress after treatments.

Figures used in the abstract

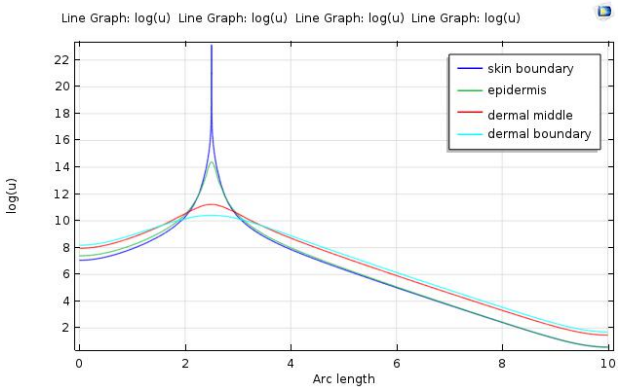

Figure 1: Fluence distribution at different layers of skin for a fixed source to target distance