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Temperature Response in Living Skin Tissue Subject to Convective Heat Flux

S. Das[1,a*], T.K. Pal[2,b], R.N. Jana[3,c], O.D. Makinde[4,d]

[1,2]Department of Mathematics, University of Gour Banga, Malda 732 103, India

[3]Department of Applied Mathematics, Vidyasagar University, Midnapore 721 102, India

[4]Faculty of Military Science, Stellenbosch University, Saldanha 7395, South Africa

[a]tutusanasd@yahoo.co.in, [b]tilakkumer@gmail.com, [c]jana261171@yahoo.co.in, [d]makinded@gmail.com

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Abstract: This paper examines the heat transfer in living skin tissue that is subjected to a convective heating. The tissue temperature evolution over time is classically described by the one-dimensional Pennes' bioheat transfer equation which is solved by applying Laplace transform method. The heat transfer analysis on skin tissue (dermis and epidermis) has only been studied defining the Biot number. The result shows that the temperature in skin tissue is less subject to the convected heating skin compared to constant skin temperature. The study also shows that the Biot number has a significant impact on the temperature distribution in the layer of living tissues. This study finds its application in thermal treatment.

Introduction

Since the beginning of the medical research, the scientists have been interesting the physiological system and its wide applications. They have tried to find the most perfect model of the human thermal system for simulating the reactions to the different environmental conditions. Like the evaluation of the every modeling process, the mathematical modeling of the human thermal system has been developing from easy to more complex ones. The heat transfer in the human body can be used to monitor important biological processes. The heat transfer in living biological tissues is of greater importance because of its many diagnostic and therapeutic applications involving either raising or lowering of temperature. Heat transfer in living tissues is a very complicated process to understand its mechanism as it involves a combination of thermal conduction in tissues, convection and perfusion of blood as well as metabolic heat generation. Advances in laser, microwave, and similar technologies have led to recent developments of thermal treatments for diseased and injured skin tissue, such as skin cancer and skin burn. The objective is to induce thermal injury precisely within tissue structures located several millimeters below the surface but without affecting the surrounding healthy tissue. Hyperthermia in cancer therapy is one of the most fundamental issues within biological tissues [1,2]. Also it has other therapeutic applications such as in cryosurgery, cryopreservation, laser surgery, thermal comfort and burn injury evaluation. Harry Pennes in 1948 initially developed a bioheat transfer model [3] for predicting heat transfer in the human forearm. Later on Wulff [4], Klinger [5], Chen and Holmes [6] proposed different bioheat transfer models. Pennes bioheat equation is based on the classical Fourier's law that depicts an infinite velocity of thermal propagation, i.e. any local temperature disturbance causes an instantaneous perturbation in the temperature at each point in the medium. This equation is an adequate model for prediction of the macroscopic temperature distribution in several biological tissues [7]. Pennes model is the first model developed to examine the process of heat transfer in the human skin. The subsequent models are significantly more complex and thus require much greater knowledge of the geometry and properties of the tissue being analyzed. Thus, as the Pennes model is simpler, it is much easier to use [8]. The thermal behavior of biological tissues during surface heating have been studied by several investigators [9-15].