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Influence of Tissue Thermophysical Characteristics and Situ-Cooling on the Detection of Breast Cancer

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Abstract

Featured Application: This article presents a numerical simulation model built using COMSOL software to study the thermophysical properties of different breast sizes. Specifically, the effects of varied blood perfusion, tumor size, location depth, and thermal conductivity were studied in relation to breast size. Pennes' bioheat formula was applied to illustrate thermal distribution by applying thermal conductivity characteristics in each layer in the breast using COMSOL software. This was followed by an emulation experiment to demonstrate the effectiveness of using situ-cooling gel on the breast surface area in providing better temperature contrast and amplifying heat detection. Simulation results demonstrated that both large breast size and small breast size both have heat detection issues, while experimental results showed how situ-cooling can help mitigate these issues. The findings offer valuable insights for future research in this field. This article presents a numerical simulation model using COMSOL software to study breast thermophysical properties. It analyzes tumor heat at different locations within the breast, records breast surface temperatures, investigates the effects of factors such as blood perfusion, size, depth, and thermal conductivity on breast size, and applies Pennes' bioheat formula to illustrate thermal distribution on the breast skin surface. An analysis was conducted to examine how changes in tumor location depth, size, metabolism, blood flow, and heat conductivity affect breast skin surface temperature. The simulation model results showed that the highest variations in skin temperatures for breasts with tumors and without tumors can range from 2.58 °C to 0.274 °C. Further, large breast size with a large surface area consistently reduces the temperature variations on the skin and might have difficulty in yielding observable temperature contrast. For small breast sizes, however, heat from tumor sizes below 0.5 cm might be quite difficult to detect, while tumors located deep within the breast layers could not produce observable temperature variations. Motivated by the above interesting results, an emulation experiment was conducted to enhance the observable heat and temperature background contrast, using situ-cooling gel applied to silicon breasts, while the tumor source was emulated using LEDs. The experiment was used to evaluate the effectiveness of adding situ-cooling to the breast surface area, and to study the modulated effect of tumor size and depth. Experimental results showed that situ-cooling enhances thermal contrast in breast thermal images. For example, for a tumor location at a depth of 10 cm, a difference of 6 °C can still be achieved with situ-cooling gel applied, a feat that was not possible in the simulation model. Furthermore, changes in tumor size and location depth significantly impacted surface temperature distribution.

Author keywords

breast cancer; Pennes bioheat equation; situ-cooling; thermography; thermophysical characteristics

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