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Review of Thermal and Physiological Properties of Human Breast Tissue

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1 Extended Abstract

Electromagnetic (EM) thermal therapies for cancer treatment, such as microwave hyperthermia (HT) and ablation (AT) therapies, aim to heat up a target tumour site to temperatures within 40-44 °C for 30-60 min (HT) or >55 °C for 5-15 min (AT). The elevated temperature increases the tumour sensitivity to radiotherapy and chemotherapy (HT), enhancing their effectiveness, or induces localised tumour cell death (AT). In studies involving the development of thermal therapy applicators, numerical simulations of a computational model are often used to investigate the heating generated within the tumour and surrounding tissues by calculating the EM and temperature fields induced by the applicator. The applicator design is then optimised to maximise energy deposition in the tumour site, while minimising the energy delivered to the surrounding healthy tissue. The temperature increase in living tissue is most often modelled using the Pennes' bioheat transfer equation [1]. After the applicator design is computationally optimised, the device is then constructed and tested on a physical phantom and numerical simulations validated with phantom experiments. In order to obtain and measure relevant temperature maps in phantoms, they must mimic the human anatomy by using mixed materials that mimic human tissue properties.

While the dielectric properties of breast tissue have been extensively studied [2] and modelled [3] to be applied to computational and physical phantoms, the thermal properties of breast tissue have not been thoroughly investigated and compiled. Both phantom testing scenarios (computational and physical phantoms) require accurate knowledge of the density, specific heat capacity, thermal conductivity, metabolic heat generation rate and blood perfusion rate of breast tissues to obtain clinically-relevant thermal distributions.

This review presents an overview of the thermal and physiological properties of human fibroglandular breast tissue, fatty breast tissue and breast tumours as found in literature. A very limited number of studies carried out measurements on human breast tissue, and an even smaller subset of these studies reported reliable measurement procedures. Density measurements proved to be the most common, whilst there were no studies on the measurement of the metabolic heat generation rate. This lack of data forced computationally based studies to estimate tissue properties which are required to conduct numerical simulations of EM thermal therapies for treatment of breast cancer. While this is necessary, the lack of agreement between various studies resulted in a wide range of values being attributed to each physical property. This review presents a reference value for each property for the three key tissues relevant for breast models: fibroglandular, fatty and tumour breast tissues. Where available, the reliable measurement data is averaged. The missing data is obtained from an average of relevant estimations made in thermal modelling studies. This compilation serves as a point of reference for future thermal studies involving numerical and physical breast models.

References

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