Blood Flow Effect in Combination of Hyperthermia with Radiation Therapy for Treatment in Breast Tumors

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Combination of hyperthermia and radiation therapy for treatment of tumors is effective. When heat is applied to tumor tissue, the tumor cells become more oxygenated, which in turn makes the cells radiosensitive. Thus, by combining the heat with radiation, lower levels of radiation can be achieved due to this increased radiosensitivity. Blood works as a temperature regulator within our bodies, making it difficult for tumors to maintain higher temperatures for a long period of time. The purpose of this research is to investigate the blood flow effect on hyperthermia by means of microbiological investigations, as well as technical experiments, computer simulations, and mathematical calculations.

In this research, 2.45 GHz microwave antenna devices, such as microstrip-patch antennas and an invasive coaxial-slot antenna, were designed to be coupled with radiation brachytherapy. These models were designed using Computer Simulation Technology (CST) 2018, a software based on the finite integration technique (FIT), and EM distribution was then calculated.

In previous experiments, static phantoms, which imitate breast tissue, were prepared and then tested using the designed antennas. Since we are able to confirm that the hyperthermia delivery was successful from the designs, the next step was to investigate how blood flow affected the results achieved from the static phantom experiments.

The dynamic phantom, as seen in Figure 1, is designed in such a way that will allow for the reproduction of blood flow within the breast. To replicate blood, the fluid utilized was saline water, while the capillaries would be represented by small filter holes above and below the main water tank area. A pump was attached to the structure, allowing for the saline water to flow throughout the imitation tissue. By attaching the microstrip-patch antenna and applying heat, due to the flow of the saline water, one can observe that the tissue reaches higher temperatures much more slowly than when no saline water was flowing through the tissue. Also, a lower final temperature was achieved. That is to say, the tissue was heated for 2 minutes per test. When the saline water was not running, temperature was able to increase much more rapidly to a total of 8ºC. In contrast, when saline water was flowing through the phantom tissue, temperature increased much more slowly to a total of 5ºC.

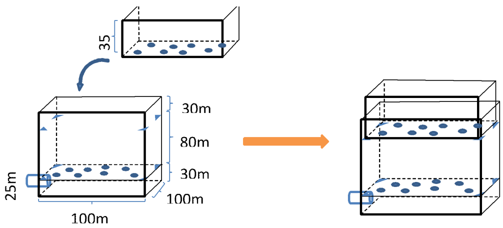

Figure 1. Dynamic phantom acrylic case; dimensions were obtained to model the average Japanese female breast size. Filter holes to imitate blood vessel function, imitation breast fat material placed inside of container. Saline water would flow through via water pump to imitate blood flow.

Studies show that tumor vasculature has high vascular density, so the blood flow in the tumor is more random and not as uniform as compared to normal tissue. By referring to Poiseuille's law equation for blood flow, we are able to calculate theoretical values for capillaries inside of a breast and tumor. For example, in breast tissue, capillary blood flow can run at approximately 2.06×10^{-7} mL/min, whereas in a tumor it can reach as high as 2.14×10^{-5} mL/min.

From our combined results within CST, the dynamic phantom experiments, and mathematical calculations, we can see the distinct differences between heating tissue without the effect of blood flow, and heating tissue with the effect of blood flow. In the future, we plan to assess a coaxial-invasive antenna, and then apply these results to real-life experimental testing.

1. Debnath, Oiendrila B, et al. "Interstitial Hyperthermia in Combination with Radiation Brachytherapy for Treatment of Breast Tumor." *Thermal Medicine*, vol. 33, no. 2, 2017, pp. 53–62., doi:10.3191/thermalmed.33.53.

2. Mankoff, D A, et al. "Blood Flow and Metabolism in Locally Advanced Breast Cancer: Relationship to Response to Therapy." *Advances in Pediatrics.*, U.S. National Library of Medicine, Apr. 2002, www.ncbi.nlm.nih.gov/pubmed/11937594.