THE ENGINEER STORY

e-ISSN: 3009 - 0792 Volume 1, 2023, 23-26.

ANALYSIS OF TEMPERATURE DISTRIBUTION ON THE BREAST CANCER TUMOUR

M. Saddam Kamarudin, Ishkrizat Taib *
Faculty of Mechanical and Manufacturing,
Universiti Tun Hussein Onn Malaysia,
Batu Pahat, Malaysia.
* Corresponding author: iszat@uthm.edu.my, saddamkamarudin@gmail.com

ABSTRACT

According to the Malaysia National Cancer Registry, cancer is one of the main causes of death in Malaysia. According to statistics, breast cancer is the most common type of cancer in Malaysia. To improve the effectiveness of radiotherapy and chemotherapy, other treatments including hyperthermia therapy are being introduced. With this process, the cancerous tissue is heated to a high temperature of 40 to 44 degrees Celsius. This study focuses on how various heat sources affect how quickly malignant breast tumours spread heat. This study will also consider malignant breast tumours of various sizes. Through the use of computational fluid dynamics (CFD), the spread of heat was modelled. In this investigation, infrared sources are imposed. To resolve the heat-generating problem, the transient Pennes Heat equation is also used. For all models, the blood vessel's speed and pressure do not significantly alter. In conclusion, this study will forecast the effectiveness of hyperthermic heat propagation onto the malignant tissue as well as the best time to generate heat on the malignant tumour.

KEYWORD
Malignant tumour, heat propagation, breast cancer, computational fluid dynamics

INTRODUCTION

A breast tumour is a condition where the breast's cells proliferate out of control. As the cancer develops malignantly over time, the cells continue to grow indefinitely, producing new cells in the process, which crowds out healthy cells and leads to additional difficulties in other parts of the body (Sinha, 2018). The aggressiveness of the tumour can cause a person with breast cancer to experience significant pain and have a negative impact on their quality of life (Paraskevi, 2012). The fact that the tumour may enlarge significantly before the symptoms manifest is one of the serious concerns with breast cancer (Weedon et al, 2008). Usually, tumour size increases linearly with tumour stage, leading to the diagnosis of cancer at an advanced stage. This created an additional issue because various tumour sizes required various therapies (Olsen, 2015). By subjecting the body to extreme temperatures, hyperthermia therapy is an alternative cancer treatment. High temperature exposure will aid in both lowering inflammation and harming cancer cells (Mostafa, 2021).

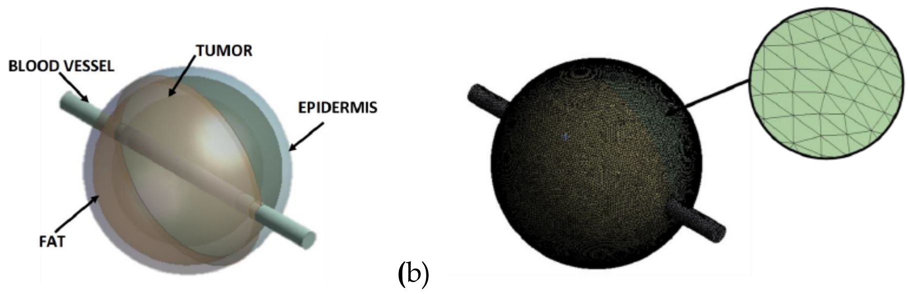
Therapies are effective against 85% of all breast tumours with hormone-positive receptors (Richard, 2008). Additionally, although not always, a variety of breast cancer forms can result in breast lumps (Allison, 2020). Due of these two characteristics, this study intends to examine how malignant breast tumours spread heat at various temperatures. The dissipation of heat applied to the breast is said to vary depending on the temperature. This study also compares the heat propagation of breast tumours of various sizes in the same scenario. Due to the tumour's inherent ability to block external heat, its size can have an impact on heat transfer. Three sizes of the tumour inside the breast are made as models of the breast at each stage, from stage one to stage three. As explained, stage one tumours are 14 mm, stage two tumours are 32 mm, and stage three tumours are 55 mm. In order to calculate the heat change when it is applied, this study will employ the Computational Fluid Dynamics (CFD) method, which uses the discretization technique in software.

MATERIAL AND METHODOLOGY

To create the models, Figure 1(a) is the dimension of the model and it is important to determine the parameter first. The value for the parameters was used as the reference to generate the model. For this research, three types of models are needed. The dimensions of the model were decided by considering the relevant value based on the previous studies. The radius of the tumours will be the manipulation variable. Table 1 shows the results of the decided value for the model's dimension. The ANSYS software's Design Modeler will be used to represent the tumour's reduced geometry. Geometry was used to calculate the influence of tumour size and location on the distribution of breast surface temperature. The three-dimensional geometry model was created for 3 different sizes of the tumour. Each model consists of four main part which is the skin layer, the fat layer at the base of the breast, the muscle chest wall and the blood vessel.

Table 1: The parameter of the model

Parameter	Dimension (mm)
Radius of epidermis	36
Radius of tissue	32
Radius of blood	10
Radius of tumour	20,40 and 60
Length of the blood vessel	72



(a) (b)

Figure 1: The dimension and the meshing of the model

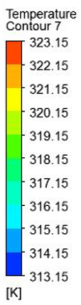
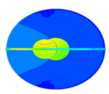
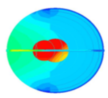
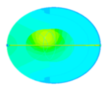
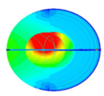
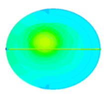
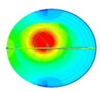
Mesh or grid refers to a small discrete cell or elements that are divided in a domain or model. At the centres of these tiny discrete cells or elements, all flow variables and other variables are solved. Mesh generation is the process of breaking down the physical domain into smaller cells or pieces. In general, high-quality CFD simulations start with a high-quality mesh because it allows for faster and more accurate simulation convergence. As a result, accurate and exact geometric mesh generation is critical, as any meshing error might have a major impact on the solution.

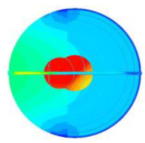
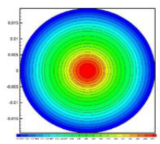
The mesh generation consists of several steps. The first step is face meshing by selecting all the surfaces of the breast cancer model. To obtain perfect meshing, this step must be done carefully on every single surface of the model. After done, volume meshing is generated by choosing the suitable type of mesh. Figure 1(b) shows the meshing of the model.

RESULT AND DISCUSSION

By adjusting the heat temperature on the model to 50ºC and 70 ºC, three different cases have been used. Model A refers to the 2mm tumour, Model B to the 4mm tumour, and Model C to the 6mm tumour. This will show how the heat can penetrate tumour tissue quite deeply. According to the findings in Table 2, the radiation had an impact on the model's blood vessels in addition to the tumour tissue. The temperature of the tumour decreases as the size of the model grows. The greater temperature in the contour may be seen to have blanketed the table above. There are also hotspots in both Models A and B that burn the surface of the tumour. Compared to the other models, Model C's high temperature on the tumour surface burned less. Table 2 compares the findings of the simulation with those from the prior study (Adhikary & Banerjee, 2016). Breast cancer temperature profiles are simulated. The graphic displays the temperature distribution based on the findings of the prior investigation. A model resembling that of the prior study was developed to ensure the validity of the result (McPherson, 2006). To obtain the result, the simulation was conducted using the same configuration. A comparison of the two results is shown in the Table 2 below. The outcome of the earlier investigation is different. Different temperatures, nevertheless, have been set. On the tumour area, the various contours are visible. This is because the tumour from the prior trial was exposed to a higher temperature than was used in the previous studies, (Francis & Sasikala, 2013) which makes it more flammable. The simulated results were less accurate than the tumour from the earlier study.

Table 2: The heat propagation in model A, model B and model C and the comparison between previous study and simulation result.

	Model	Heat Propagation	
	A		
	B		
	C		

	Simulation result
	Previous study

CONCLUSION

The outcomes demonstrate how radiation can affect blood vessels. The blood vessel's temperature reveals that it rises and stabilises with only a small amount of variation along the blood vessel (Saddam et al, 2022) At the end, the temperature did, however, significantly drop. This is due to a decrease in the amount of heat that may enter the circulation as the tissue gets bigger. Additionally, the primary cause of the temperature and blood flow fields' instability is the surface temperature. Operating at greater temperatures, as shown by Model A, enables heat to penetrate the tumour more deeply. However, the high temperature that reaches the tumour is rather low when compared to other models. This might be because the tumour was exposed to radiation when it was still small. Less heat enters the tumour as the tumour grows larger (Kamarudin et al, 2022)

ACKNOWLEDGEMENT

This research has been supported by the Ministry of Higher Education (MOHE) through the Fundamental Research Grant Scheme (FRGS) (FRGS/1/2020/TK0/UTHM/03/5).

REFERENCE

Adhikary, K. and Banerjee, M., (2016). A Thermofluid Analysis of the Magnetic Nanoparticles Enhanced Heating Effects in Tissues Embedded with Large Blood Vessel during Magnetic Fluid Hyperthermia. J. Nanoparticles, vol. 2016, pp. 1–18.

Allison, K. H. (2020). Estrogen and progesterone receptor testing in breast cancer: American society of clinical oncology/college of American pathologists guideline update. Arch. Pathol. Lab. Med., vol. 144, no. 5, pp. 545–563.

Francis, S. V., & Sasikala, M. (2013). Automatic detection of abnormal breast thermograms using asymmetry analysis of texture features. Journal of medical engineering & technology, 37(1), 17–21.

Kamarudin, M.S. , Taib, I. , Syafinaz, I. (2022). Analysis of Heat Propagation on Difference Size of Malignant Tumor. Journal of Advanced Research in Applied Sciences and Engineering Technology.

McPherson, K., Steel, C.M., Dixon, J.M. (2006). Breast cancer: Epidemiology, risk factors and genetics. In Dixon, J.M. (ed) ABC of breast diseases (3rd edition) London: Blackwell Publishing.

Mostafa Yusefi, Kamyar Shameli, & Siti Nur Amalina Mohamad Sukri. (2021). Magnetic Nanoparticles In Hyperthermia Therapy: A Mini-Review. Journal of Research in Nanoscience and Nanotechnology, 2(1), 51–60.

Olsen Ø. E. (2015). Why measure tumours?. Pediatric radiology, 45(1), 35–41.

Paraskevi T. (2012). Quality of life outcomes in patients with breast cancer. Oncology reviews, 6(1), e2.

Richard Linforth (2008). Cancer Research UK . Breast cancer key facts. Accessed via info.cancerresearchuk.org/cancerstats/types/breast/

Saddam Kamarudin, M. , Taib, I. , Nasir, N.F. (2022) Comparison of Heat Propagation Properties in Different Sizes of Malignant Breast Tumours using Computational Fluid Dynamics. Journal of Advanced Research in Applied Sciences and Engineering Technology.

Sinha, T., (2018). Tumors: Benign and Malignant. Cancer Ther. Oncol. Int. J., vol. 10, no. 3, pp. 1–3.

Weedon-Fekjaer, H., Lindqvist, B. H., Vatten, L. J., Aalen, O. O., & Tretli, S. (2008). Breast cancer tumor growth estimated through mammography screening data. Breast cancer research : BCR, 10(3), R41.