

# Prediction of Heat Distribution on Brain Malignant Tumor Using Hyperthermia Therapy

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**Abstract:** The malignant brain tumor is cancer which is not controlled by the cells of the brain, and which produces new cells until normal cells are overwhelmed and body system problems are caused. There are several treatments that people normally do, but it has a side effect on the body. Based on previous study, hyperthermia is a treatment that can reduce the size of tumor with less side effect to the surrounding tissue. The method of hyperthermia treatment is applied to this study which is the heat is applied to the tumor with certain temperature and time treatment. This research focuses on heat distribution to a different temperatures of malignant brain tumor. Other's thing that needs to find out is comparison on heat distribution of brain tumor for different temperature with different depth of tumor inside the brain. The CFD is applied in these cases and Ansys Fluent is used to run the simulation. The heat source that used in this study is infrared. For all simulation, a time considered is 500 seconds and a time step is 0.1 second. From the result obtained, the tumor temperature is increase due to the increasing of temperature that is applied to the skin from the heat source. For the different position of tumor, the heat was not penetrated well due to the depth of the tumor inside the brain. The temperature also needs to be rise if the tumor were growth deep inside the brain, but it needs some study on temperature and time treatment that want to use. The size of the tumor did not affect the temperature of the tumor, as the simulation results demonstrated that the temperature remained constant, but the position depth of tumor give the biggest effect on heat to penetrate. The heat generation of the tumor is affected the temperature that comes out from the tumor. This research study also helps the medical expert in improving the efficiency of the treatment based on heat distribution with different temperature.

**Keywords:** Hyperthermia, brain tumor, CFD, Ansys Fluent

## 1. Introduction

Cancer refers to one of the several conditions defined by an unregulated breakdown of anomalous cells, capable of invasion and degradation of normal corporal tissue. Cancer will also spread all over your body in unexpected ways. Previous study shows that cancer was the leading cause of death in industrialized countries while death was a second leading cause in developed countries [1]. Some researchers also stated that 85% of human cancers are caused by solid tumors liked mesothelioma, sarcomas, lymphomas, sarcomas as well as cancers of the breast, prostate, kidney, ovaries, pancreas, thyroid, and colon. In 2018, 18.1 million new diagnoses and 9.6 million deaths from cancer were announced by the World Health Organization [2]. In this study, heat will be used as one of the treatment therapies in which heat is a form of energy [3] that transfer from one body to another as the result of a

difference in temperature. The basic concept of heat flow is from high temperature to low temperature [4] as the low temperature need some device to drive it to the high temperature. Heat energy also transferred through some concept which is conduction is physically contact, convection is the movement of fluids and radiation is emitted electromagnetic energy [4]. On the other hand, heat transfer in living organism's biological systems is very necessary in several physiological processes since the function is essential [5].

The treatment that uses heat is called hyperthermia therapy. Hyperthermia is a condition in which body will be exposed to the higher temperature [5] than normal body temperature 37°C. The best heat treatment for hyperthermia is known when the treatment does not give the side effects to normal tissues. It is because, the

exposure of heat to surrounding tissue may give the side effects as it can make normal tissue damage. Furthermore, in this study it will be one design model for brain tumor that being created using SolidWorks 2019 and it should be saved as a IGS file before import to ANSYS software. There is one size of tumor with spherical shape and three positions of the tumor in brain that will be run for this study. The tumor will be at center of the brain, but the depth is different. SOLIDWORKS and Computational Fluid Dynamic (CFD) are applied to figure out this study.

Cancer has been one of the deadliest diseases people have encountered over past decade, and it has no specific cause and no definitive treatment [6] found it yet. Therefore, hyperthermia is one of the ways to treat cancer, but the treatment gives different effect on patient depending to the heat generation of the nanoparticle that been injected to the patient. Due to the process, the heat also will expose to the surrounding tissue and muscle. The distribution of heat will give big effect in the process where too much heat will damage both cancer cell and human tissue. Therefore, what is the suitable heat distribution in the process, so that hyperthermia will increase the temperature without overheating and damaging the surrounding tissues.

This research will examine the distribution of heat based on the heat sources which is infrared in the different position of tumor in brain. It mainly focuses on determination of the heat flow on malignant brain tumors using hyperthermia therapy. Besides that, this research will investigate the distribution of heat (infrared) flow on malignant tumors using hyperthermia therapy and will determine the effectiveness of hyperthermia therapy using infrared toward brain tumor.

## 2. Previous Work on Hyperthermia

Basically, hyperthermia treatment is divided by two which is local hyperthermia and regional hyperthermia, and each treatment has their own benefit to heal the cancer patients. Hyperthermia therapy not only improves the role of the immune system, but it is also appealing since it is physically less risky to care than chemotherapy and radiation, and repeated therapy can be done without regard to cumulative toxic side effects [7]. For local hyperthermia, it was the one of the most popular treatment strategies for cancerous tumors near the skin surface or near the natural body orifices.

Furthermore, local hyperthermia also usually used for the treatment of local cancer by raising the temperature of tumors if normal surrounding tissues are not damaged [8]. There are many studies have proved that local hyperthermia can enhance the immunity of anti-tumors in human body [9]. Besides that, [10] that in treatment of human papillomavirus (HPV) infected skin lesions, local hyperthermia in the range temperature of  $42^{\circ}\text{C} - 49^{\circ}\text{C}$  has been used successfully with adequate tolerance and low adverse effects.

Hyperthermia is cancer cytotoxic and functions as a chemo sensitizer and a radiation agent [11]. As for regional hyperthermia, it is defined as a target-specific therapy and six descriptions of hyperthermia are suggested to counteract the pleiotropic effect of this treatment method to growth and development of tumors [12]. However, regional hyperthermia is typically used to treat illness in deeper tissues or in large areas of the body, including the limb and organ, with a temperature rise of  $43^{\circ}\text{C}$  for two hours [8]. The regional hyperthermia usually combined with others therapy treatment which is chemotherapy or radiation therapy due to the temperature of treatment is not enough to destroy the cells cancer.

### 2.1 Stage of hyperthermia

Hyperthermia happens in three phases which are heat cramps, heat exhaustion, and heat stroke, and this happened when the body's core temperature starts increasing as the latest one is the most extreme. An early sign of heat illness and dehydration can be heat cramps. Usually, people complain of cramping in the muscles that are exercised that cannot be healed by stretching. Following extreme, sustained exercise, cramps may occur and result from water loss and body electrolyte imbalances such as sodium, potassium, and calcium. It is also possible to experience physical fatigue and dizziness (famous in younger participants). More prone are poorly acclimatized athletes [13]. To prevent more severe thermal injuries, it is necessary to treat the athlete immediately.

Heat exhaustion is a more extreme heat disease that is attributed to intense sweating caused by excessive loss of body fluids. Profuse sweating, cool, clammy, and pale skin and a weak, fast pulse are characterized by this condition. Usually, the athlete is lightheaded, experiences chills or shivering and is unable to focus. This can lead to heat stroke [14] if left untreated, which is a rare, acute, life-threatening injury that sometimes results in serious brain damage or death. The variations between heat fatigue and heat stroke are also not that straight cut. Signs and symptoms that related to heat exhaustion can be seen and have a core temperature suggesting heat stroke.

Heat stroke is a medical tragedy that needs urgent medical attention and is characterized by three main symptoms that are greater than  $40^{\circ}\text{C}$  in rectal temperature [15], marked mental confusion or unconsciousness, and shock. It is likely that the person will not sweat, and their skin will be hot, dry and red. People will have a quick and bounding pulse, and their breathing will be swift and deep. However, rectal temperature is the most accurate way to detect heat stroke.

## 3. Methodology

This methodology explained detail about the steps and procedure that involve in the simulation by using computational fluid dynamics (CFD). This research is to simulate the heat distribution on the brain malignant tumor.

### 3.1 Flowchart

Figure 1 below shows the planning flow chart from early stage to the last stage of tumors. The flow chart that has been arranged was considering all aspects and very detailed to make sure the simulation always on track and can be done within its time as planned.

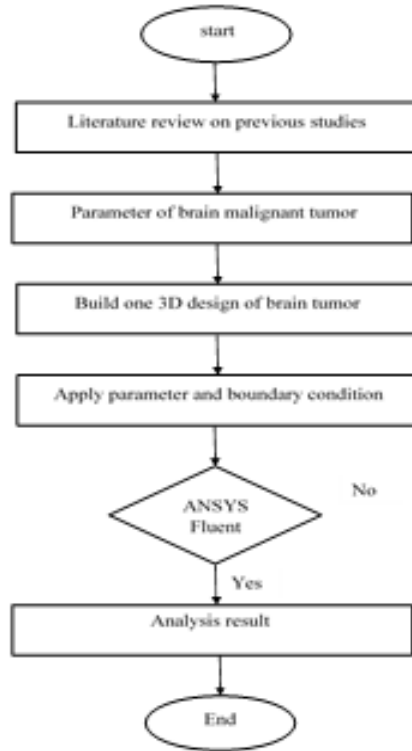


Fig. 1 – The flowchart of the simulation process

### 3.2 Boundary conditions and meshing

All the equation that used in the CFD is based on the following principle where it can be expressed in mathematical equation term. However, it can be change in partial differential equation or it can be call as Navier-Stokes Equation. Each boundary condition must be specified and input the whole parameter. In this study, the skin thickness that will be consider is 5 mm while the skull thickness is within the range 6 mm until 28 mm. As for the heat, it is applied to the brain model by heat source. There is one heat source that used for this research which is infrared.

Table 1 shows the physical properties of the skin, skull, brain, and tumor that will used in this study to run the simulation. In this study, the heat generation only consider at tumor with the value is 8750000 w/m<sup>2</sup> and it is obtained from [16]. Based on previous study, the tumor temperature is higher than the body temperature and it is called as abnormal tissue in human body.

Table 1 – Physical properties

|                              | Skin  | Skull | Brain | Tumor |
|------------------------------|-------|-------|-------|-------|
| Density (Kg/m <sup>3</sup> ) | 1100  | 1028  | 1046  | 1090  |
| Specific heat (J/Kg. K)      | 3770  | 850   | 3630  | 3421  |
| Thermal conductivity (W/m.K) | 58.15 | 16.5  | 0.51  | 0.49  |

The analysis of the brain tumor with position of the tumor 8mm from the top of the brain based on mesh setup is shown in Table 2. The mesh setup was selected from second GIT that consisted of 277168 nodes. The mesh setup is focusing on the tumor than the brain, skull, and skin. It is because the tumor was placed inside deep of the brain. The brain model geometry only has one size but the position of the tumor that placed inside the brain were different. In this study, it will have three different positions of the tumor inside deep of the brain because there's no specific position for the tumor growth. The different position of tumor does not affect the values for nodes and elements because the size of tumor reminds same.

Table 2 – Mesh detail for GIT

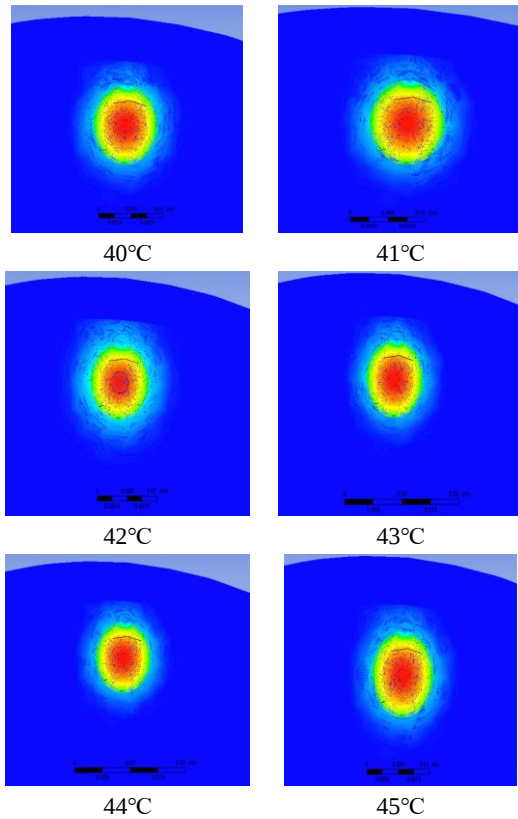
| Meshing            | Setup       |
|--------------------|-------------|
| No. of nodes       | 277168      |
| No. of elements    | 1545694     |
| Smoothing          | Medium      |
| Orthogonal max.    | 0.900000    |
| Minimum            | 1.4187e-004 |
| Maximum            | 0.84965     |
| Average            | 0.21958     |
| Standard deviation | 0.12162     |

The temperature analysis of the hyperthermia brain model is focusing on the temperature distribution between tumor and brain. Besides that, the temperature distribution for brain tumor model and heat sources for infrared is set into 7 different temperatures between 40°C to 45°C.

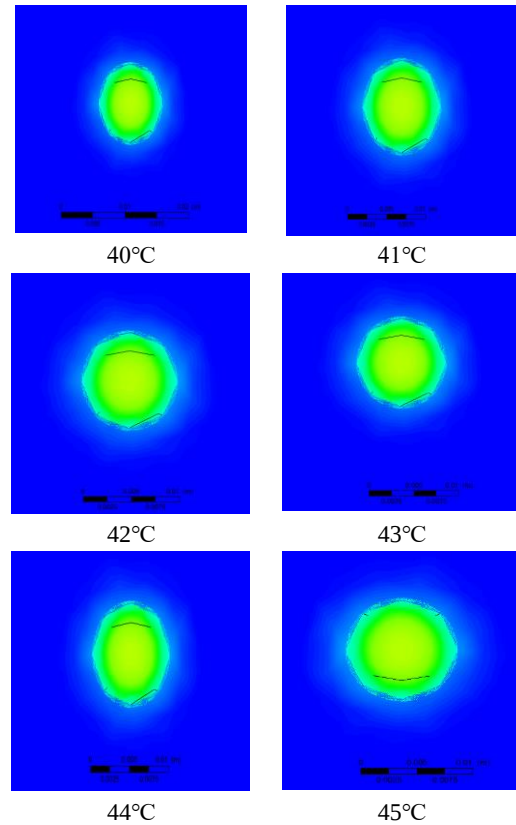
## 4. Results and Discussion

The simulation results due to shape, position of tumor from top of brain, and the temperature used in this study. So, the result shows the different temperature started from 40°C until 45°C that really penetrate to the tumor according to the position of tumor from the top of brain. Figure 2 to 4 shows the simulation results for temperature distribution with different positions and of tumor and temperature.

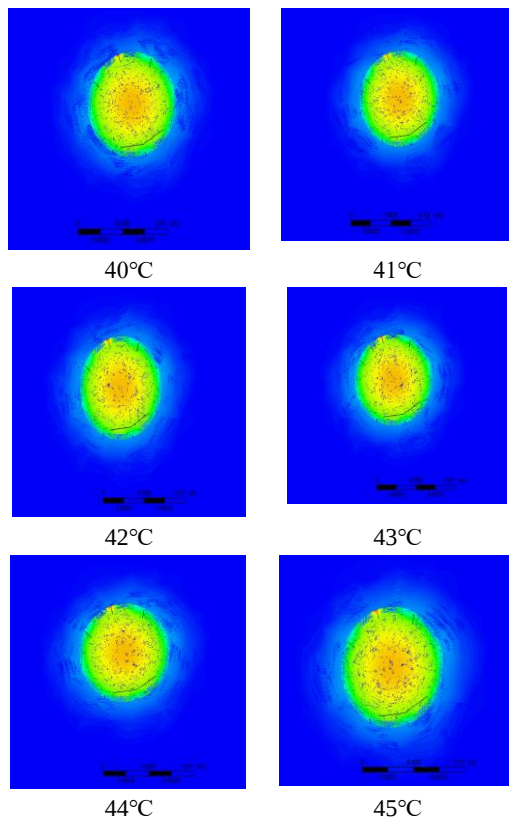
Based on the result from the figures, the best heat distribution and penetration that can fully covered the tumor is 8 mm from the top of the brain. Based on the result given, the heat used at 40°C which indicates the lowers heat temperature used in this study, the simulation result shows the heat still can fully covering the tumor at the lowers temperature set within 8minutes. The other heat temperature set which is the higher temperature in this study and the value is 45°C, shows the heat distribution and heat penetration are fully covered the tumor. It can be assumed that the tumor is effect to the heat according to previous study [17] that mentioned the heat can reduce the percentage size of the tumor. However, the tumor can be cure by using heat but its take time because the temperature needs to manage wisely to make sure that heat not making a damage on surrounding tissues.



**Fig. 2 – Temperature penetration on tumor located 8 mm from top of brain**



**Fig. 4 – Temperature penetration on tumor located 15 mm from top of brain**



**Fig. 3 – Temperature penetration on tumor located 10 mm from top of brain**

In this case, the purpose of the study was to investigate the heat distribution on brain tumor which the heat sources used are infrared. In this study, the infrared with 39°C to 45°C temperature is relevant to use if the tumor deep from the top is 8 mm due to the simulation result given at the Table 3. Furthermore, when the heat was applied to the skin, the tumor will produce reaction such as heat because the tumor has its own heat generation. The heat from the tumor will go through to the surrounding. Increasing the temperature from the heat source will make the temperature at tumor increase also. Based on this study, the heat generation of the tumor is affected the temperature distribution because tumor temperature is linearly increase due to the temperature applied from the heat source. In this study, it can be concluded that suitable temperature and time to treat the tumor seriously need to be emphasis due to the distribution of heat that will give impact on surrounding tissue.

## 5. Conclusion

Results of the simulation reveal the distribution of heat towards malignant tumor. According to results, the heat is really penetrated and distributes around 40°C until 45°C in the depth of 8mm from the top of the brain. The results also reveal that the heat is don't give any side effect to the surrounding area (brain, skin and skull) because the temperature and time treatment were managed wisely.

In overall, the objective of this study has been achieved. The objective is to determine the heat flow on malignant brain tumors using hyperthermia therapy, to investigate the distribution of heat (infrared) flow on malignant tumors using hyperthermia therapy and to investigate the effectiveness of hyperthermia therapy using infrared toward brain tumor.

There are several recommendations that need to done in the next study which are the geometry of modelling should not be too complex which can make meshing and setup process not difficult, a meshing should be more focusing at the complex or critical area to make the result more accurate, a max skewness mesh should be lower and

it will make the result more accurate and can minimize the error from obtain, the heat source that uses should be higher gap to show the result is more different and the temperature uses need to be added if the position of the tumor was different.

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