Applied Mathematical Sciences, Vol. 12, 2018, no. 4, 175 - 183
HIKARI Ltd, www.m-hikari.com
https://doi.org/10.12988/ams.2018.712368

Bio-Heat-Transfer Equation (BHTE) Analysis in Cancer Cell Using Hyperthermia Therapy Case Study in Ambon Moluccas Indonesia

Alwi Smith

Biological Education Department, Education Faculty
Pattimura University, Moluccas, Indonesia
Address: Ir. M. Putuhena Street Poka, 97233, Moluccas, Indonesia

Abstract

Hyperthermia is one of the method in medical treatment simulation to overcome the cancer disease. In hyperthermia, it is used the electromagnetic wave as heat source in human body heat transfer. This heat transfer is mathematically simulated by Bio-Heat-Tranfer-Equation (BHTE). In this research, the boundary heat treshold in muscle, fat and tumor related to hyperthermia therapy is being predicted.

Keywords: Cancer, Hyperthermia, boundary heat treshold, Bio-Heat-Transfer-Equation

Introduction

Cancer is one of the common terminology to express the malignant neoplasma [1]. Literally, neoplasma means “new growth”. Wills said that cancer is abnormal mass in tissue which is uncontrollably grown so that disturb the normal tissue growth [4].

Cancer is one of the death main cause in development country. In United States and another several development country, they have 25% of cancer death. During a year, it is about 0,5% of their population diagnosed have a cancer [2]. This condition is not the same one as in Moluccas.

According to Malukunews.com newspaper in 25 Juni 2015, in Indonesia, especially in Moluccas, the local government has held a lot of efforts in cancer handling program. Moluccas local health department has held the papsmer check up and examination on 400 citizens of Ambon. According to its result, there is no citizen invected by cancer. Local government of Ambon together with the Singapore national cancer centre doctor team, give socialization related to the head, neck and breast cancer to the 200 of womens. Furthermore, these womens can also closely consult about their health to them. All of these effort is purposed to obstruct the growth of cancer sufferer in Ambon, Moluccas.

Hyperthermia is one of the method in medical treatment simulation to overcome the cancer disease. Hyperthermia use the electromagnetic wave as heat source to transfer the heat in human body. This heat transfer is simulated by Bio-Heat-Tranfer-Equation (BHTE) mathematically. In this research, the boundary heat treshold in muscle, fat and tumor related to hyperthermia therapy is being predicted.

Bio-Heat-Transfer Equation (BHTE)

Bio-het-transfer-equation (BHTE) is an equation in medical planning in hyperthermia treatment simulation. In hyperthemrnia medical treatment use the electromagnetic wave which play roles as heat source to transfer the heat in human body. The bio-heat-transfer-equation is given as follow:

$$\rho c \frac{\partial T}{\partial t} = \nabla(k \nabla T) - C_b W(T - T_b) + ARD$$

where ρ represent the density of tissue, c is a certain heat, k is the thermal conductivity, W represents the blood perfussion, T is temperature, and ARD is the period source. This equation means that the blood perfussion (W) use the non linear version to fat perfusion which related to the muscle. This blood perfussion is not depended to the temperature. However, several experiment shows that blood vessels in tissue to get the heat into cancer is depends to the temperature.

If the heat is given to the normal tissue, such as skin and muscle, then the heat will increase significantly. So, the blood perfussion and normal tissue in muscle, fat and tumor combination is needed to have the nonlinear version of

equation. According to this condition, this model depends on the blood heat perfussion and tumor. So, we get the following blood perfussion in muscle, fat and tumor [3]:

$$W_{muscle} = 4{,}0 - 1{,}0723(T - 45)^4 \quad (1)$$

$$W_{fat} = 0{,}72 - 0{,}0682(T - 45)^4 \quad (2)$$

$$W_{tumor} = 0{,}833 - 0{,}468(T - 45)^4 \quad (3)$$

Result and Discussion

In bio-heat-transfer-equation related to the hyperthermia therapy, each variable is influenced one another within the temperature (*T*). The data of the patient condition can be seen in Table 1.

Table 1. Clinical Pathalogy and Analomy Result

No	Patient Initial	M/F	Age	Hb	Leuco	Led	Tromb	D.L	D.T	D.O
1	ARB	M	50	75	4,400	65-120	300.000	-	0,720	-
2	AUM	F	55	50	7,400	74-120	453.000	0,05	-	-
3	RLO	M	61	60	2,400	76-120	348.000	-	-	-
4	STA	F	36	81	10,400	60-120	474.000	-	-	-
5	YRI	M	48	62	9,400	70-120	345.000	-	-	0,650

(Source: Ambon Dr.M Haulussy Hospital, 2016)

Let $T_0 = 0$ so $f(T) < 0$ and $T_1 = 45$ so $f(T) > 0$. According to Table 1, we found that $W_{muscle} = 0{,}650$. So, from Equation (1) we get that:

$$W_{muscle} = 4{,}0 - 1{,}0723(T - 45)^4$$

$$0{,}650 = 4{,}0 - 1{,}0723(T - 45)^4$$

Let $Y_0 = f(T_0)$, $Y_1 = f(T_1)$ and $Y_t = f(T_t)$, so we get:

$$Y_0 = (4{,}0 - 0{,}650) - 1{,}0723(0 - 45)^4 = -4{,}397096937500 \cdot 10^6$$

$$Y_1 = 3{,}35 - 1{,}0723(45 - 45)^4 = 3{,}35$$

From the equations above, we get the nonlinear equation of bio-het-transfer of blood perfussion. The first step is to find the initial point of its solution using Table 2. From Table 2, we can see that for the interval $T = [43{,}44]$ is where the solution placed.

Table 2. Iteration of initial points of W_{muscle} solution

Iteration	***T***	$Y_t = f(T_t)$
1	0	-4,3970969375000.E+06
2	10	-1,6091169375000.E+06
3	20	-4,1886393750000.E+05
4	30	-5,4281937500000.E+04
5	40	-6,6693750000000.E+02
6	41	-2,7125880000000.E+02
7	42	-8,3606300000000.E+01
8	43	-1,3906800000000.E+01
9	44	2,1777000000000.E+00

So, we can get the solution with its error tolerance is $e = 0.001$as the following Table 3. In table 3 shows that the temperature solution of W_{muscle} is 43,701 F with its eror is $0{,}000431854$. So, for patient with initial name YRI bestly have the 43,701 F temperature related to the muscle hyperthermia therapy.

Table 3. The solution of W_{muscle} equation with its error

Iteration	**T**	**Y**	**T-new**	**error**
0	43	-13,9068		
1	44	2,1777	43,865	0,003086571
2	43,865	1,4680	43,586	0,006426047
3	43,586	-1,0544	43,701	0,002678992
4	43,701	0,2025		0,000431854

Let $T_0 = 0$ so $f(T) < 0$ and $T_1 = 45$ so $f(T) > 0$. According to Table 1, we found that $W_{fat} = 0{,}05$. So, from Equation (2) we get that:

$$W_{fat} = 0{,}72 - 0{,}0682(T - 45)^4$$

$$0{,}05 = 0{,}72 - 0{,}0682(T - 45)^4$$

Let $Y_0 = f(T_0)$, $Y_1 = f(T_1)$ and $Y_t = f(T_t)$, so we get:

$$Y_0 = (0{,}72 - 0{,}05) - 0{,}0682(0 - 45)^4 = -2{,}796619550000 \cdot 10^5$$

$$Y_1 = 0{,}67 - 0{,}0682(45 - 45)^4 = 0{,}67$$

The initial point of W_{fat} nonlinear equation solution can be selected from Table 4 below.

Table 4. Iteration of initial points of W_{fat} solution

	Iteration	***T***	$Y_t = f(T_t)$
1	0	-2,7966195500000.E+05	
2	10	-1,0234195500000.E+05	
3	20	-2,6639955000000.E+04	
4	30	-3,4519550000000.E+03	
5	40	-4,1955000000000.E+01	
6	44	6,0180000000000.E-01	
7	45	6,7000000000000.E-01	
8	50	-4,1955000000000.E+01	

From Table 4, we can see that the temperature solution is in the interval $T = [40{,}44]$. Then, we can see the solution of temperature in W_{fat} nonlinear equation as described in Table 5. In Table 5 we get that the temperature solution of W_{fat} is 43,356 F with its eror is $0{,}000540082$. So, for patient with initial name AUM have the 43,356 F of temperature treshold related to the fat hyperthermia therapy.

Table 5. The solution of W_{fat} equation with its error

Iteration	T	Y	T-new	error
1	40	-53,2050		0.000987662
2	44	58,3800	43,957	0.000987662
3	43,957	56,7827	42,413	0.036389224
4	42,413	-3.1897	43,723	0.029964616
5	43,723	44,1026	43,564	0.003653078
6	43,564	30,3674	43,212	0.008142409
7	43,212	-21,0294	43,356	0.003320473
8	43,356	40,8227		0.000540082

Let $T_0 = 0$ so $f(T) < 0$ and $T_1 = 45$ so $f(T) > 0$. According to Table 1, we found that $W_{tumor} = 0{,}720$. So, from Equation (3) we get that:

$$W_{tumor} = 0{,}833 - 0{,}468(T - 45)^4$$

$$0{,}72 = 0{,}833 - 0{,}468(T - 45)^4$$

Let $Y_0 = f(T_0)$, $Y_1 = f(T_1)$ and $Y_t = f(T_t)$, so we get:

$$Y_0 = (0{,}833 - 0{,}72) - 0{,}468(0 - 45)^4 = -1{,}919092387000 \cdot 10^6$$

$$Y_1 = 0{,}113 - 0{,}468(45 - 45)^4 = 0{,}113$$

The initial point of W_{tumor} nonlinear equation solution can be seen from Table 6.

Table 6. Iteration of initial points of W_{tumor} solution

Iteration	T	$Y_t = f(T_t)$
0	0	-1,9190923870000.E+06
1	10	-1,7541088150000.E+06
2	20	-1,5999987550000.E+06
3	30	-1,4562736150000.E+06
4	40	-1,3224560350000.E+06

Table 6. (Continued): Iteration of initial points of W_{tumor} solution

5	41	-1,1969500000000.E+02
6	42	-3,7795000000000.E+01
7	43	-7,3750000000000.E+00
8	44	-3,5500000000000.E-01
9	45	1,1300000000000.E-01

From Table 6, we can see that the interval $T = [40,44]$ included the temperature solution of W_{tumor} nonlinear equation. Furthermore, we can see the solution of temperature in W_{tumor} nonlinear equation as described in Table 7.

Table 7. The solution of W_{tumor} equation with its error

Iteration	**T**	**Y**	**T-new**	**error**
1	44	-0,3550		
2	45	0,1130	44,759	0.005394567
3	44,759	0,1114	27,847	0.607290285
4	27,847	-40512,0219	44,759	0.377834204
5	44,759	0,1114	44,758	1.03904E-06
6	44,758	0,1114	40,534	0.104209807
7	40,534	-185,9993	44,756	0.094323841
8	44,756	0,1113	44,753	5.64316E-05
9	44,753	0,1113	40,728	0.098825726
10	40,728	-155,7034	44,751	0.089879126
11	44,751	0,1112	44,748	6.41406E-05
12	44,748	0,1111	40,991	0.09165753
13	40,991	-120,8298	44,744	0.083891138
14	44,744	0,1110	44,741	7.69991E-05
15	44,741	0,1109	41,272	0.084036437
16	41,272	-90,2466	44,737	0.077434015

Table 7. (Continued): The solution of W_{tumor} equation with its error

17	44,737	0,1107	44,732	9.49138E-05
18	44,732	0,1106	41,580	0.075811266
19	41,580	-63,9104	44,727	0.070355759
20	44,727	0,1104		0.000121332

In Table 7 we get that the temperature solution of W_{tumor} is 44,727 F with its eror is $0{,}000121332$. So, for patient with initial name ARB have the 44,727 F of temperature treshold related to the tumor hyperthermia therapy.

Conclusion

From this research, it is shown that the treshold temperature solution related to hyperthermia therapy is determined differently in each patient. It is depend on their blood perfussion in each organ. For the patient with initial YRI bestly have the 43,701 F temperature related to the muscle hyperthermia therapy, for patient with initial name AUM have the 43,356 F of temperature treshold related to the fat hyperthermia therapy and for patient with initial name ARB have the 44,727 F of temperature treshold related to the tumor hyperthermia therapy.

References

[1] F. Macdonald, C.H.J. Ford, Elizabeth Hospital, A.G. Casson, *Molecular Biology of Cancer*, Second Edition, Garland Science/BIOS Scientific Publishers, London, 2005.

[2] WHO and National Cancer Institute (NCI), 2014. Cancer Mortality and Morbidity, Accesed in 21st of March 2015. http://www.who.int/en/

[3] Bodo Erdmann, Jens Lang and Martin Seebab, Adaptive Solutions of Nonlinear Parabolic Equations with Application to Hyperthermia Treatments, *Proceedings of the International Symposium on Advances in Computational Heat Transfer*, Berlin – Dahlem, 1997. https://doi.org/10.1615/ichmt.1997.intsymliqtwophaseflowtranspphencht.90

[4] Lumungga, *Dukungan Sosial Pada Pasien Kanker*, USU Press, Medan. Indonesia, 2009.

Received: January 12, 2018; Published: February 8, 2018