Mahindra University Research Symposium 2k20

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Computational Modelling of Bio-heat Transfer Problem for Cancer Detection and Treatment

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Abstract:

- The aim of the present work is to develop one and two-dimensional computational models to study bio-heat problems in tumour cells, using Finite Difference Method.
- The Penne's bio-heat equation is discretized using Crank Nicholson scheme based finite difference method and is solved iteratively.
- The results for one-dimensional model are validated with existing analytical solutions.
- The model is further extended to study the behaviour of tissue embedded with tumour using two-dimensional rectangular coordinates.
- Temperature profiles for healthy tissue and tissue embedded with tumour are obtained and effect of tumour position and size are observed.
- The model is further extended to model heat treatment of tumour using magnetic hyperthermia.

Introduction:

- Bioheat transfer is a branch of biomedical engineering which is derived from the fundamentals of heat transfer.
- Cancer is one of the most widespread and fatal diseases across the world. Several methods of treatment for cancer have been developed over the years.
- Transferring heat to the infected cell is one such method. The thermal properties and behavior of unhealthy tissues show significant deviation from that of the healthy tissue.
- The aim of this study is to develop a one and two-dimensional computational model to study thermal behavior of cancer.
- Penne's bio-heat equation is a continuum model, and is used vastly in thermal treatment models of cancer.
- Hyperthermia is used for a wide variety of therapeutic applications, especially for treating cancer. The treatment objective of the current therapy is to raise tumour temperature higher than 43°C for periods of more than 30 to 60 minutes, while keeping temperatures in the surrounding normal tissue below 43°C.
- Magnetic hyperthermia is induced by the introduction of nanoparticles in an oscillating magnetic field to shrink the tumour.

Modelling and methodology:

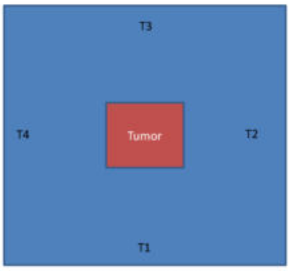

Figure 1. *Schematic of 2D tissue with embedded tumour*

Pennes Bio-heat transfer equation

$$\rho C \frac{\partial T}{\partial t} = \nabla . k \nabla T + \omega_b \rho_b C_b \left(T_a - T\right) + Q_m + Q_r \quad (1)$$

- The above equation is discretized using finite difference method for the one-dimensional case and for tumor in rectangular coordinates.
- The number of nodes have been decided based on the grid independent study.
- The discretized equations are solved using Successive Over Relaxation method(SOR).
- A numerical code is developed in C with appropriate boundary conditions.
- The solutions obtained from the developed model are validated against analytical results for one-dimensional problem.

Results:

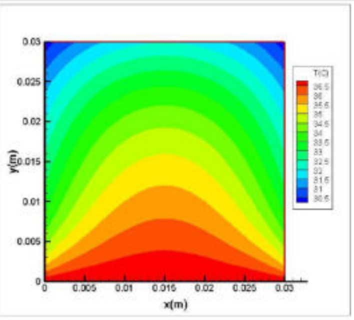

Figure 2. *Healthy tissue without presence of tumour*

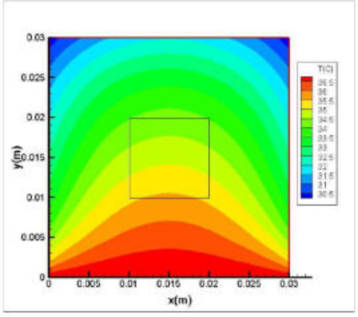

Figure 3. *Tumour of size* $0.01 \times 0.01\ sq.m$ *at x=0.015m and y=0.015m*

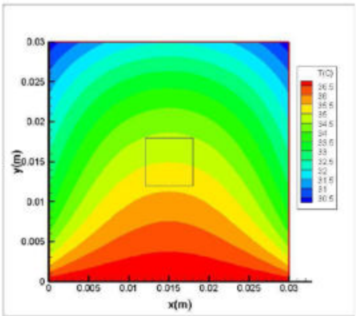

Figure 4. *Tumour of size* $0.006 \times 0.006\ sq.m$ *at x=0.015m and y=0.015m*

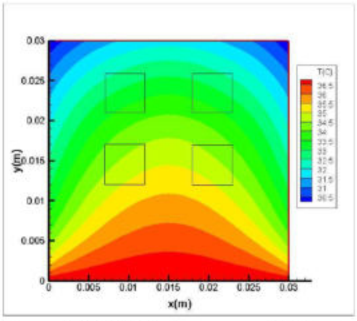

Figure 5. *Multiple tumours at different locations*

Magnetic hyperthermia

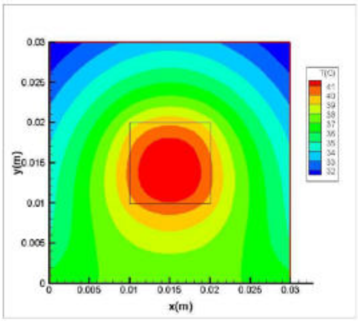

Figure 6. $Q_r = 1.5 \times 10^5 (W/m^3)$

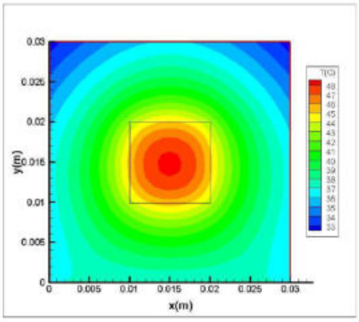

Figure 7. $Q_r = 2.0 \times 10^5 (W/m^3)$

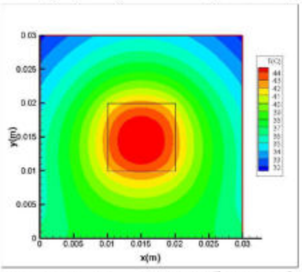

Figure 8. $Q_r = 2.5 \times 10^5 (W/m^3)$

Conclusion:

- A computational model has been developed using finite different method, to solve Penne's Bioheat Transfer for one and two dimensional cases.
- The temperature distribution in diseased tissue deviates from that of healthy tissue and it is affected by the position and size of the tumour.
- In magnetic hyperthermia, it is observed that the higher the power density, the higher the temperature reached in a given time period.

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