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Sun Pharma Science Scholar Award Committee

Subject: Justification for Research Work - Sun Pharma Science Scholar Award

Dear Members of the Sun Pharma Science Scholar Award Committee,

I am writing this letter to provide a comprehensive justification for the research work conducted by Gangadhara B and Supervised by Dr.Panchatcharam Mariappan which we believe deserves strong consideration for the Sun Pharma Science Scholar Award.

The research work titled "A vector finite element approach to temperature dependent parameters of microwave ablation for liver cancer" is a groundbreaking study which is accepted in reputed jounal "International jounal of numerical methods for biomedical engineering" and National Library of Medicine that addresses a critical issue in the field of Microwave Ablatin treatment. Below are the key justifications for why this research work stands out as an exceptional contribution to the scientific community:

Research Problem

Ninety percent of cancer-related deaths are caused by hepatocellular carcinoma, which is the fourth most common type of liver cancer. The best therapies for hepatocellular carcinoma patients are liver transplantation and surgical procedures since they reduce the chance of developing new tumors. Oncologists advise minimally invasive procedures such as local ablative techniques and liver resection due to patients' habits, the location of the tumor, and a lack of adequate donors. For the treatment of cancer, a variety of ablative methods have been employed, including cryoablation, radiofrequency ablation, and microwave ablation. Cryoablation is a form of thermal ablation that involves liquid nitrogen or argon to freeze unwanted cells during the treatment. One of the most used thermal ablation methods for treating cancer is radiofrequency ablation, which employs radio waves to create heat inside the tumor. Microwave ablation (MWA), a local ablative technique, uses microwave energy to kill unwanted cells. During MWA, the antenna is inserted inside the liver to transfer the microscopic energy at a frequency of 2.45 Ghz. A single-slot coaxial antenna with a slot size of 1 mm was used to produce adequate heat in the liver. Rapid and uniform heating, higher intramural temperatures, reduced susceptibility to heat sinks, a shorter ablative duration, and a bigger ablative volume are benefits of MWA over radiofrequency ablation. Since microwave ablation can generate extreme heat around tumor cells and damage neighboring healthy cells, it presents a significant difficulty.**Therefore, Mathematical models and accurate numerical methods are required to analyse the heat deposition before the treatment. Hence, in this work, we modified the existing models and used a new numerical technique to increase the accuracy of the heat distribution profile.**

Methodology Three physical phenomena mathematically define microwave ablation: **1) Microwave absorption in the liver, 2) Heat distribution in the liver, and 3) Cell response to heat**. The microwave absorption in the tissue is modeled by a wave propagation equation with perfect electric boundary and absorbing boundary conditions. Penne's bio-heat equation analyzes heat distribution in the liver by considering specific heat absorption terms as external heat sources. Once heat distribution in the liver was known to us, we used the cell death model to know whether cells were dead or alive.

The governing equations mentioned in the previous section are solved by using numerical techniques instead of analytical methods due to the complex geometry and non-linearity in the equation. The VFEM and FEM are used to solve the electromagnetic equation and bioheat equation, respectively. The time derivative in the bioheat equation is discretized using the unconditionally stable Euler backward scheme. In order to determine how much heat is distributed throughout the liver, the simulation first solves Maxwell's equations with boundary conditions. The tumor is modeled as a sphere with a radius of 2 cm, whereas the liver is modeled as a cylinder with a height of 8 cm and a radius of 4 cm. The geometry and dimensions of the antenna are depicted in Figure 3. The domain is discretized using tetrahedral and triangular elements in Gmsh. A fine mesh is created inside the antenna and around the antenna's tip in order to obtain an accurate approximation. The FEniCS is used to solve the system of partial differential equations with the help of Nedelec and Legrange elements. A core i5 intel 10^{th} generation CPU with 8GB memory RAM was used for simulation.

Results

- The Specific absorption rate and heat distribution is studied for input power 50 W and frequency 2.54 GHz
- Pulstaing power introduced to control the thermal damage to healthy cells in during the liver
- Numerical results are compared with the experimental results to validate the models, parameters, and numerical techniques
- Temperature-dependent parameters (specific conductivity, thermal conductivity of liver and blood) are introduced in the model to get accurate solutions
- We calculated the ablation volume of $22cm^3$ and $20cm^3$ for numerical methods, VFEM and FEM, respectively.
- We studied the computation time between FEM and VFEM

Conclusion This study used the VFEM formulation to solve Maxwell's equation to calculate the SAR and external heat source. The SAR profile obtained by the VFEM provides more accurate values than the FEM when compared with experimental results. The FEniCS(dolfin 2019.2.0) is used to simulate the model. Further, the VFEM takes less time to calculate the SAR profile than the FEM. When the input power is constant and dielectric properties are independent of temperature, for approximately 0.193 million elements, the computation time is 3 hours irrespective of the FEM or the VFEM formulation. However, irrespective of the power input, when dielectric properties are temperature dependent, the computation time for the VFEM is approximately 6.7 hours for heating time 10 min with the adaptive time stepping technique, whereas the FEM takes 8 hours. The coupled bio- heat equation and three-state cell death model were used to investigate the shape and size of the ablation zone. The ablation zone volume is higher when the VFEM formulation replaces the FEM in SAR computation. Since the real-time prediction of the ablation zone is important in the radiology field, replacing the FEM with the VFEM formulation can provide better accurate results in lesser computation time

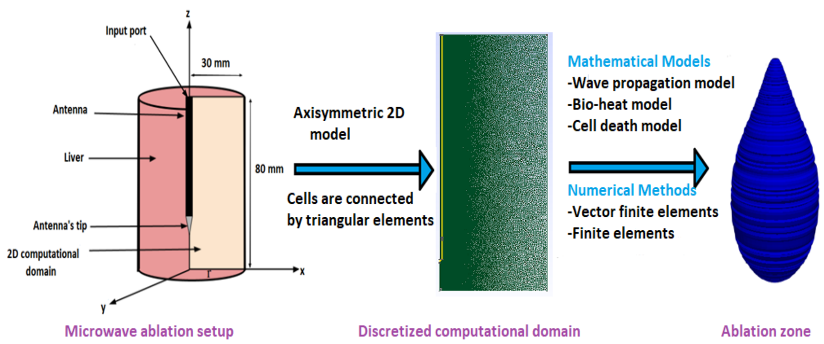

Figure 1: **Graphical representation**

Referenc

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