CANCER DETECTION USING COAGULATION THERAPY WITH COAXIAL ANTENNA

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Abstract: Nearly seven lakh Indians die of cancer every year, while over 10 lakh are newly diagnosed with some form of the disease. Surgical resection is not always feasible in patients with hepatocellular carcinoma. Microwave coagulation therapy (MCT) has been used as an alternative to resection, and its efficiency has been evaluated in tissue microwave irradiation from a dipole antenna causes water molecules in the dielectric substance to vibrate dramatically at a frequency of 2.45GHz.
MCT has the advantage over other thermal ablation technique in that ablation is rapid and the area of ablation is immediately hypoechic on real time ultrasound monitoring and therefore completeness of ablation can be easily monitored.in this treatment .Invasive technique is used in which thin microwave coaxial antenna is inserted into the tumour to produce the coaguted region including the cancer cells. Finite element method is an technique used for performing analysis of complex structures.

Keywords: MCT, FEM, Coaxial antenna, Thermal coagulation.

1. Introduction

Cancer is a general term used to refer to a condition where the body's cells begin to grow and reproduce in an uncontrollable way. These cells can then invade and destroy healthy tissue, including organs. Cancer sometimes begins in one part of the body before spreading to other parts. These extra cells lump together to form a growth or tumour. Two types of tumours exist, benign and malignant. Begin tumour are not cancerous. The cells in benign tumours don't spread and it is rare for a benign tumour to be life threatening. Malignant tumours on the other hand, are cancerous. The cells in them are abnormal and divide randomly and chaotically. The cells behave aggressively and attack the tissue around them. They also can jump away from the malignant tumour and enter the bloodstream or lymphatic system to form new tumours in other parts of the body. This type of spread is known as metastasis. We are studying about pancreatic cancer liver cancer, kidney cancer and ovarian cancer.

1.1 Pancreatic Cancer

Generally, pancreatic cancer is type of cancer which is almost always given top priority. Pancreatic cancer is a malignant neoplasm originating from transformed cells arising in tissues forming the pancreas. Pancreatic cancer begins in the tissues of the pancreas, which aids digestion and metabolism regulation. The most common type of pancreatic cancer, accounting for 95% of these tumours, is adenocarcinoma (tumours exhibiting glandular architecture on light microscopy) arising within the exocrine component of the pancreas. A minority arise from islet cells, and are classified as neuroendocrine tumours. Detection and early intervention are difficult because it often progressives stealthily and rapidly. There is also a lack of oncologists specialised in treating pancreatic cancer in India and the cost of treatment is very high. According to Delhi Cancer registry, Mizoram in India has the highest prevalence of pancreatic cancer. "In Aizawl, Mizoram, prevalence rate is 2.3 per 100,000 people per year against the global rate of 1 per 100,000 people per year".

1.2 Liver Cancer

Liver cancer is one of the most common forms of cancer around the world, but is uncommon in the different areas, according to the Mayo Clinic. Primary liver cancer is the fifth most frequently diagnosed cancer globally and the second leading cause of cancer death. Liver cancers are malignant tumours that grow on the surface or inside the liver. They are formed from either the liver itself or from structures within the liver, including blood vessels or the bile duct. Liver cancers should not be confused with liver metastases, also known as secondary liver cancer, which is a cancer that originate from organs elsewhere in the body and migrate to the liver. However, its rates in America are rising. Most liver cancer that occurs in the U.S. begins elsewhere and then spreads to the liver. A closely related cancer is intrahepatic bile duct cancer, which occurs in the duct that carries bile from the liver to the small intestine. Nearly 19,000 people are expected to die from liver and intrahepatic bile duct cancer in recent years, according to the NCI.

1.3 Kidney cancer

Kidney cancer is a type of cancer that starts in the cells in the kidney. The two most common types of kidney cancer are renal cell carcinoma (RCC) and urothelial cell carcinoma (UCC) of the renal pelvis. The different types of kidney cancer (such as RCC and UCC) develop in different ways, meaning that the diseases have different outlooks (orprognosis), and need to be staged and treated in different ways.

1.4 Ovarian cancer

Epithelial ovarian cancer is by far the most common form of ovarian cancer. Germ cell and stromal ovarian cancers are much less common. Ovarian cancer can also result from a cancer somewhere else in the body that has spread. Ovarian cancer was the No. 4 cause of cancer death in women between 2003 and 2007, according to the NCI. The median age of women diagnosed with it is 63. The cancer is easier to treat but harder to detect in its early stages, but recent research has brought light to early symptoms that may aid in diagnosis, according to the Mayo Clinic. Those symptoms include abdominal discomfort, urgency to urinate and pelvic pain. Nearly 14,000 women are expected to die of ovarian cancer in 2010, according to the NCI.

Microwave coagulation therapy (MCT) is emerging as an attractive modality for thermal therapy of soft tissues targeted in short periods of time, making it particularly suitable for ablation of hepatic and other tumours.

2.Antenna Design

Finite Element Method is an efficient technique used for performing analysis of complex structure allowing the flexibility in changing the shape of the antenna. This method consist of representing a given domain, however it may be by geometrically simple shapes over which the approximation functions can be systematically derived. A 2D finite element model (FEM) is developed to determine the absorbed power and the temperature distribution surrounding the single thin microwave coaxial antenna using COMSOL multiphysics. Developed antenna model for FM analysis consist of a thin coaxial cable with a 1mm wide ring shaped slot cut on the outer conductor 6 mm from the short circuited tip. For hygienic purpose, the antenna in enclosed in a sleeve (catheter) made of PTFE (polytetra fluoro ethylene a biocompatible dielectric material).The antenna is operated at 2.45 GHz, a frequency widely used in microwave coagulation therapy. The geometry of the antenna is modeled in 2D, and analyzed with variable dimension of slot having, 1mm, 1.2mm, 1.5mm and 1.7mm distances from the tip. The geometry with 1.5mm slot of the coaxial antenna is shown below; The cable is short circuited at the tip and a ring shaped slot, 1.5 mm wide, is cut at 6mm distance from the tip. The radial dimensions of the pin, as much as the position and axial dimension of the slot were found to provide the optimal energetic coupling between the microwave source and the tissue. The COMSOL multiphysics user interface contains a set of CAD tool for geometry modelling in 2D, 3D coaxial antenna designed in the CAD environment.

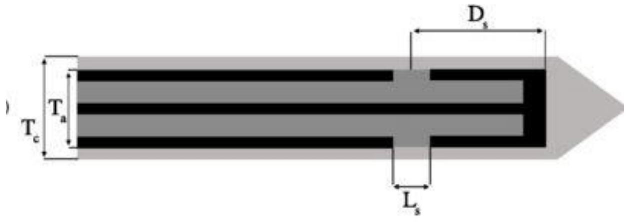

Fig.1 (a) coaxial antenna design

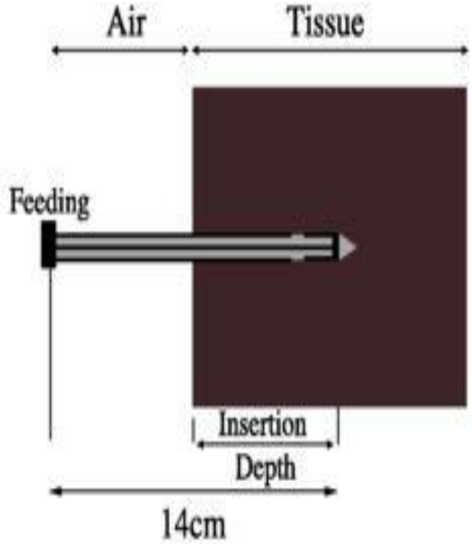

Fig.1 (b) coaxial antenna inserted in tissue

3.Model Definition

Electromagnetic heating appears in a wide range of engineering problem and is ideally suited for modelling in COMSOL multiphysics because of its multiphysics capabilities. This example comes the area of hyperthermic oncology and it models the electromagnetic field coupled to the bio-heat equation. In hyperthermic oncology, cancer is treated by applying localized heating to the tumour tissue, often in combination with chemotherapy or radio-therapy.

3.1 Domain and Boundary Equations-Electromagnetics

An electromagnetic wave propagating in coaxial cable is characterized by transverse electromagnetic fields (TEM).Assuming time-harmonic field with complex amplitudes containing the phase information equation are;

$$\boldsymbol{E} = \boldsymbol{e_r}\frac{\boldsymbol{C}}{\boldsymbol{r}}\boldsymbol{e}^{\boldsymbol{j(\omega t - kz)}}$$

$$\boldsymbol{H} = \boldsymbol{e_\varphi}\frac{\boldsymbol{C}}{\boldsymbol{Z}}\boldsymbol{e}^{\boldsymbol{j(\omega t - kz)}}$$

$$\boldsymbol{P_{av}} = \int_{r_{inner}}^{r_{outer}} \boldsymbol{R_e}\left(\frac{1}{2}\,\boldsymbol{E} \times \boldsymbol{H^x}\right) \boldsymbol{2\pi r dr}$$

$$= \boldsymbol{e_z \pi}\frac{\boldsymbol{C^2}}{\boldsymbol{Z}}\boldsymbol{ln}\left(\frac{\boldsymbol{r_{outer}}}{\boldsymbol{r_{inner}}}\right) \qquad (1)$$

Where Z is the direction of propagation, and r,z are cylindrical coordinate centered on the axis of the coaxial cable. Pav is the time-averaged power flow in the cable, Z is the wave impedance in the dielectric of the cable, while inner and router is the dielectric's inner and outer radiations, respectively. Further, ω denotes the angular frequency. The propagation constant, k, relates to the wavelength in the medium, λ, as;

$$k = \frac{2\pi}{\lambda} \quad (2)$$

In the tissue, the electric field also has a finite axial component whereas the magnetic field is purely in the azimuthal direction. Thus, the model antenna using an axisymmetric transvers magnetic(TM) formulation. The wave equation then becomes scalar in;H_φ

$$\nabla \times \left(\left(\frac{1}{\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}} \right) \nabla \times H_\varphi \right) - \mu_r k_0^2 H_0 = 0 \quad (3)$$

The boundary conditions for the metallic surfaces are;

$$n \times E = 0$$

The feed point is modeled using a port boundary condition with a power level set to 10 W. This is essentially a first-order low-reflecting boundary condition with an input field: $H_{\varphi 0}$

Where $$H_{\varphi 0} = \frac{\sqrt{\frac{p_{av} Z}{\pi r \ln\left(\frac{r_{outer}}{r_{inner}}\right)}}}{r} \quad (4)$$

for an input power of **Pav** deduced from the time-average power flow. The antenna radiates into the tissue where a damped wave propagates. Because discretize only a finite region, truncate the geometry some distance from the antenna using a similar absorbing boundary condition without excitation.

3.2 Domain and Boundary Equations-Heat Transfer

The bio-heat equation describes the stationary heat transfer problem as;

$$\nabla.(-k\nabla T) = \rho_b C_b \omega_{b(T_b - T)} + Q_{met} + Q_{ext} \quad (5)$$

Where k is the liver's thermal conductivity (W/(m·K)), ρb represents the blood density (kg/m3), Cb is the blood's specific heat capacity (J/(kg·K)), and ωb denotes the blood perfusion rate (1/s). Further, Qmet is the heat source from metabolism, and Qext is an external heat source, both measured in W/m3.This model neglects the heat source from metabolism. The external heat source is equal to the resistive heat generated by the electromagnetic field:

$$Q_{ext} = \frac{1}{2} R_e[(\sigma - j\omega\varepsilon)E.E^*] \quad (6)$$

The model assumes that the blood perfusion rate is ωb = 0.0036 s−1, and that the blood enters at the body temperature Tb = 37 °C and is heated to a temperature, T. The blood's specific heat capacity is Cb = 3639 J/(kg·K).

4.Scientific Computing

Finite element method was employed for the numerical modeling and analysis of the antenna. It involves dividing a complex geometry into small elements for a system of partial differential equation, evaluated at nodes or edges. The microwave source is set at the upper end of the coaxial cable. The material volume which is inserted in the antenna is shown at table 1. The propensity of the tissue to produce heat in the presence of the time variable electric field is determined by the values of its electric properties such are conductivity, relative permittivity, and thermal conductivity. The value of electric properties is shown in table 2.

.Table 1- Parameters for model.

NAME	VALUE	DESCRIPTION
Rho_blood	1000kg/m^3	Density of blood
Cp_blood	3639J/(kg.k)	Specific heat,blood
Omega_blood	0.0036000 1/s	Blood perfusion rate
T_blood	310.15 K	Blood temperature
Eps_diel	2.03	Relative permittivity, Dielectric
Eps_cat	2.6	Relative permittivity, Catheter
Frequency	2.45GHz	Microwave frequency
P_in	10[W]	Input microwave power

Table 2: Dielectric properties of some main organs at 2.45GHz.

ORGAN NAME	ELECTRIC CONDUCTIVITY(1/S)	RELATIVE PERMITIVITY	THERMAL CONDUCTIVITY(w/m*k)
Liver	1.69	43.03	0.560
Kidney	2.43	52.74	0.539
Pancreas	1.97	57.20	0.441
Ovary	2.264	44.7	0.52

Figure2 and 3 show the temperature and surface distribution in the liver tissue with 2D modeling at the end of the heating process (the steady state),in a longitudinal plane.

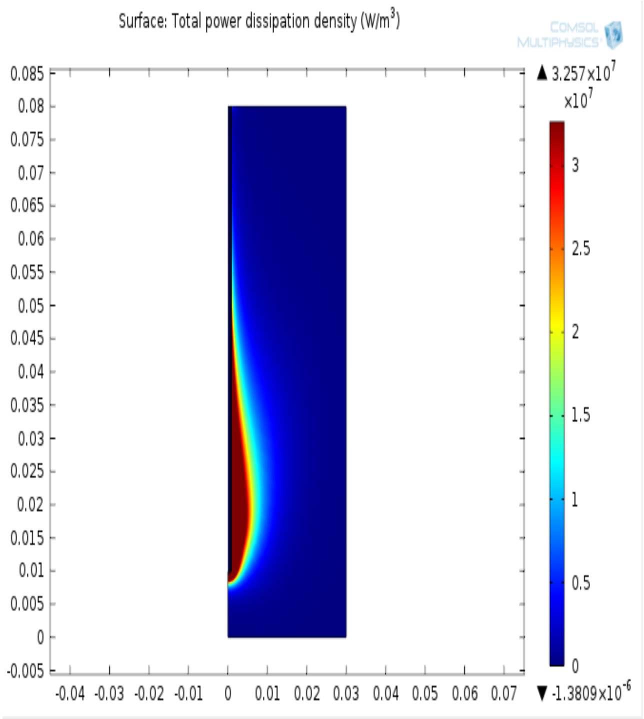

Fig.2 Temperature Distribution in the Liver Tissue.

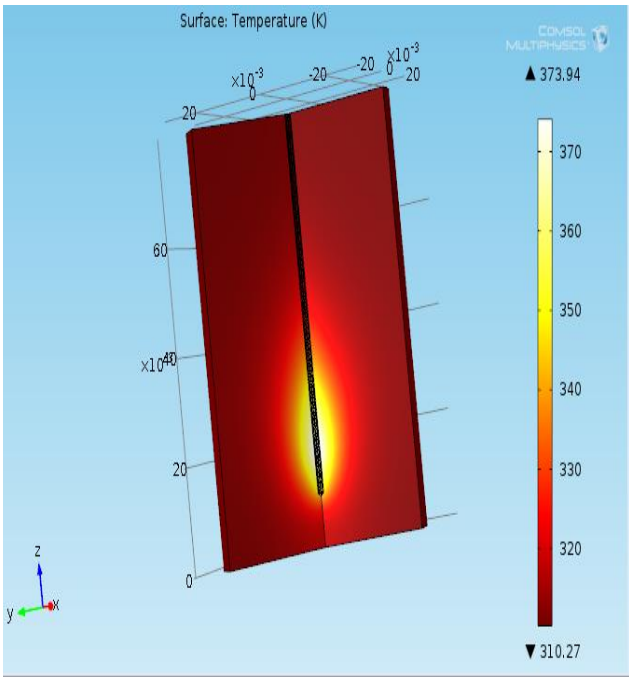

Fig.3 Surface Temperature in the Liver Tissue.

Figures 4 and 5 show the temperature and surface distribution in the pancreas tissue.

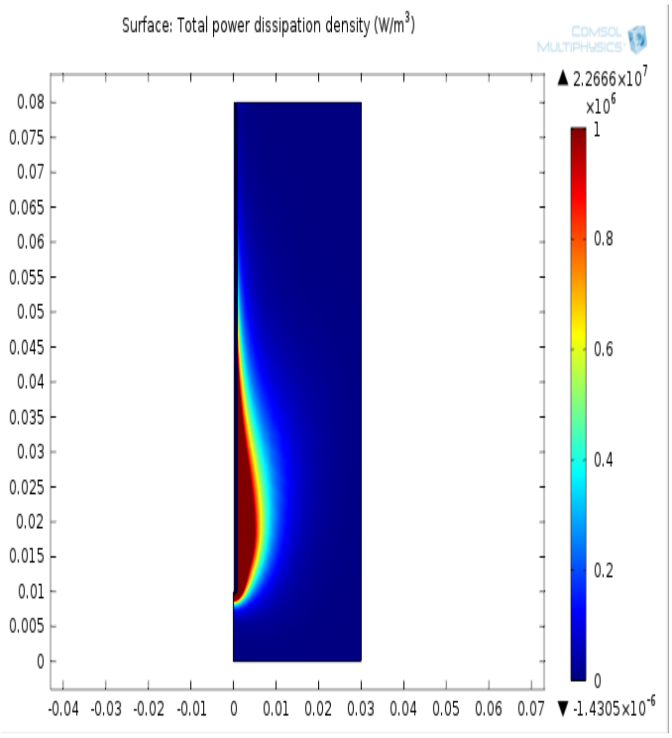

Fig 4 Temperature Distribution in the pancreas Tissue.

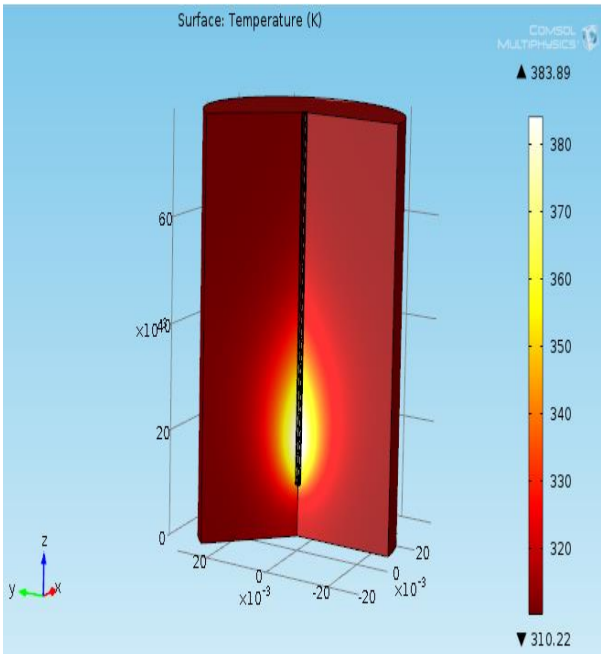

Fig 5 Surface Temperature in the pancreas Tissue.

Figures 6 and 7 show the temperature and surface distribution in the Kidney tissue.

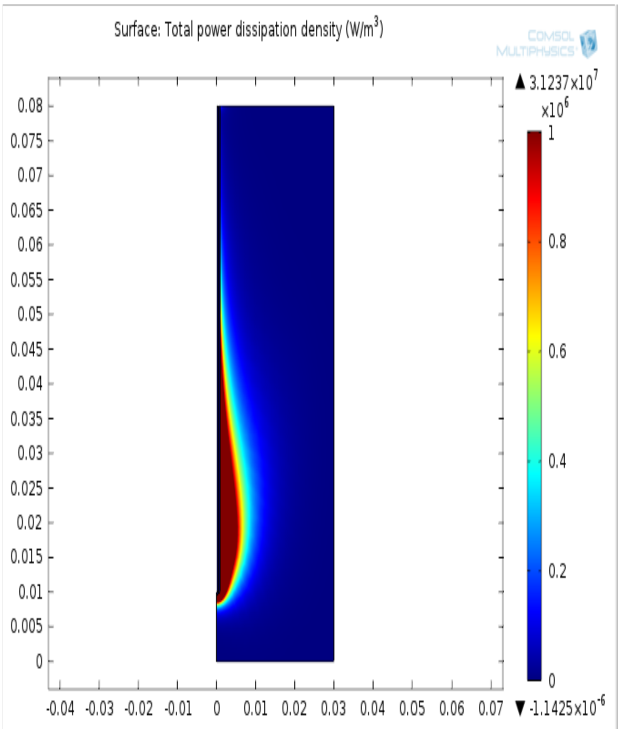

Fig 6 Temperature Distribution in the kidney Tissue

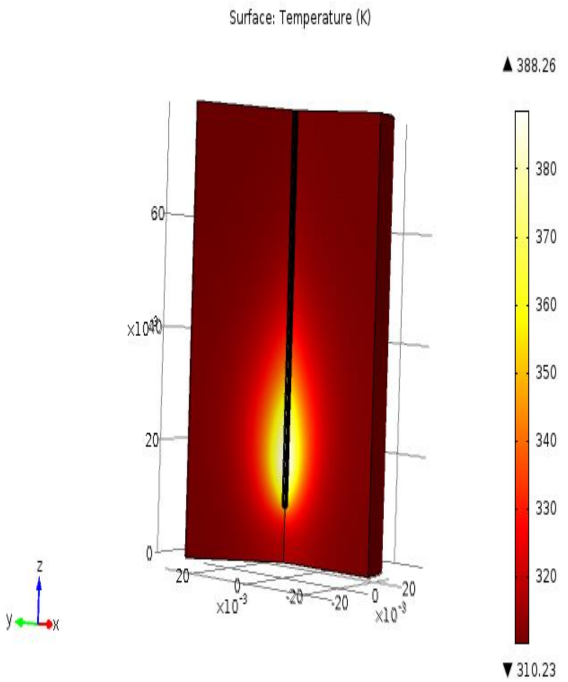

Fig.7 Surface Temperature in the Kidney Tissue.

Figures 8 and 9 show the temperature and surface distribution in the ovarian tissue.

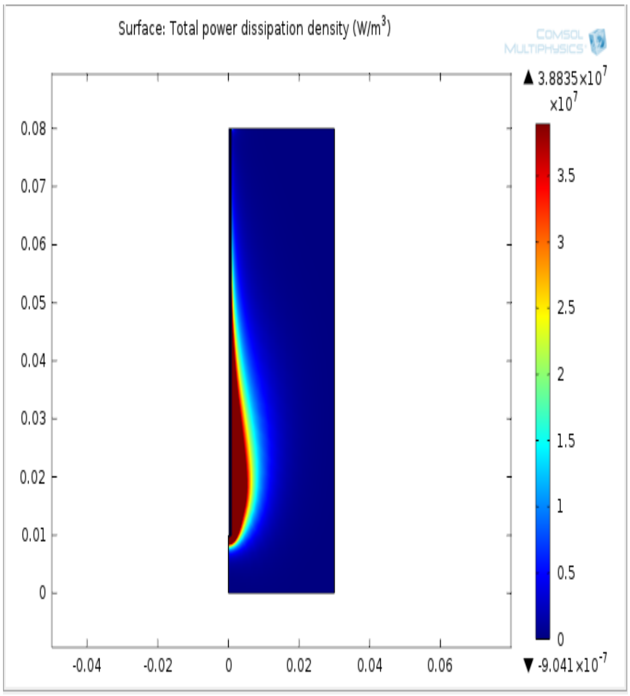

Fig.8 Temperature Distribution in the Ovarian Tissue.

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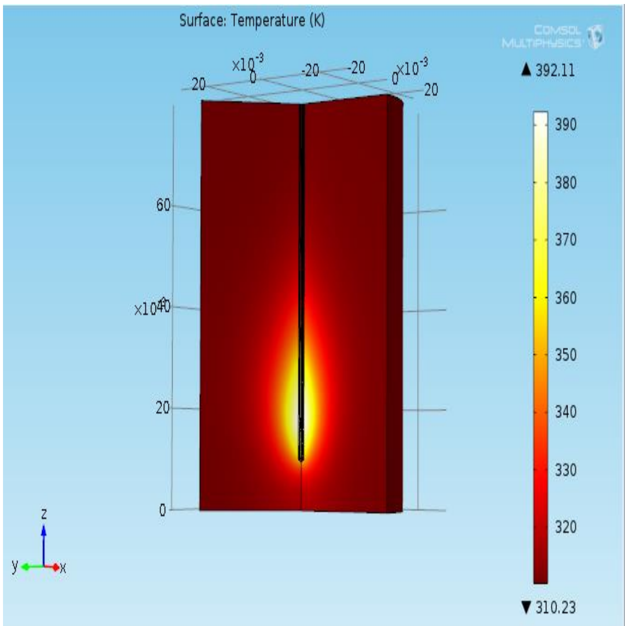

Fig.9 Surface Temperature in the Ovarian Tissue.

5.Result and Discussion

The resulting steady-state temperature distribution in the tissue for an input microwave power of 10w.Thetemperature is highest near the antenna. It has been observed that with 10 w input tissue absorved which are shown in table 3.

Table 3: Absorved power in Tissue

ORGAN NAME	TOTAL POWERDISSIPATION(W)
Liver	9.35301
Kidney	9.58875
Ovary	9.62706
Pancreas	9.30545

Heating power deposited in the liver tissue is computed for different designs with varying slot dimension as shown in Figs.10 to 13.

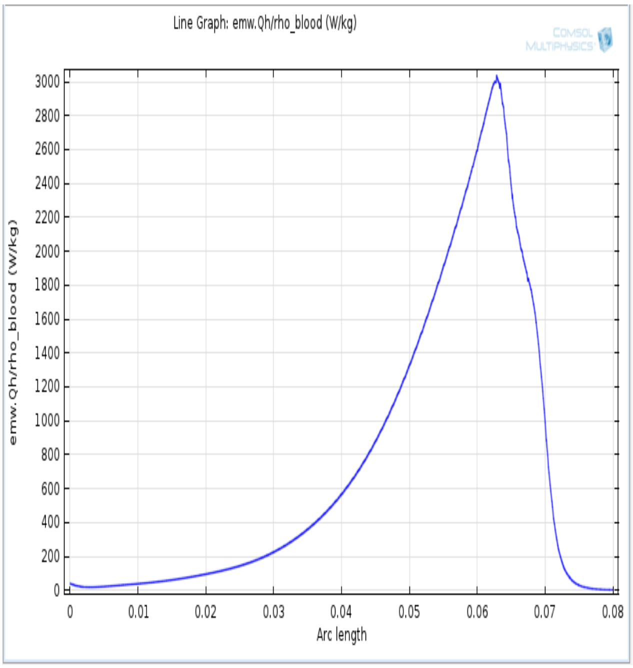

Fig .10 Normalized SAR value of Liver Tissue.

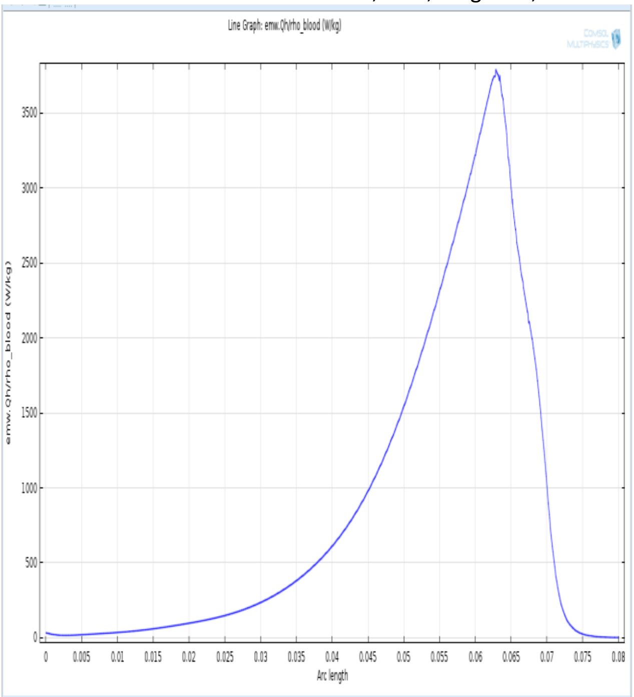

Fig.11 Normalized SAR value of kidney Tissue.

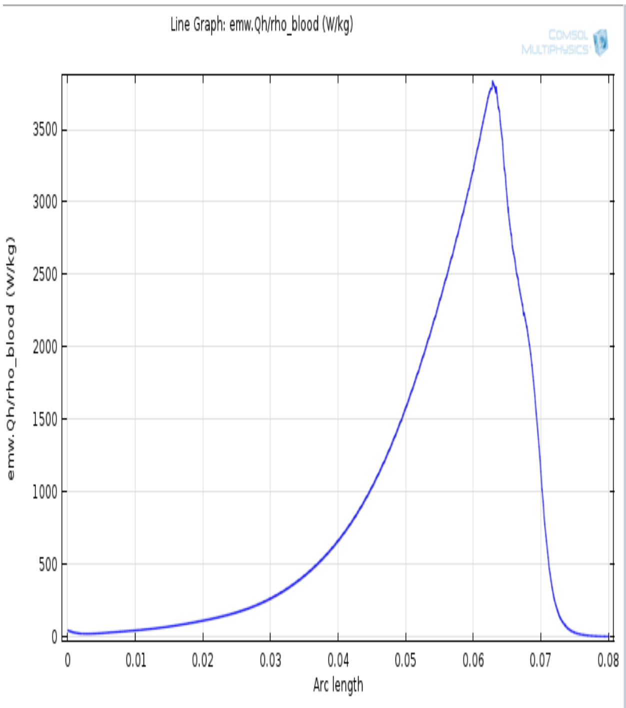

Fig.12 Normalized SAR value of Ovary Tissue.

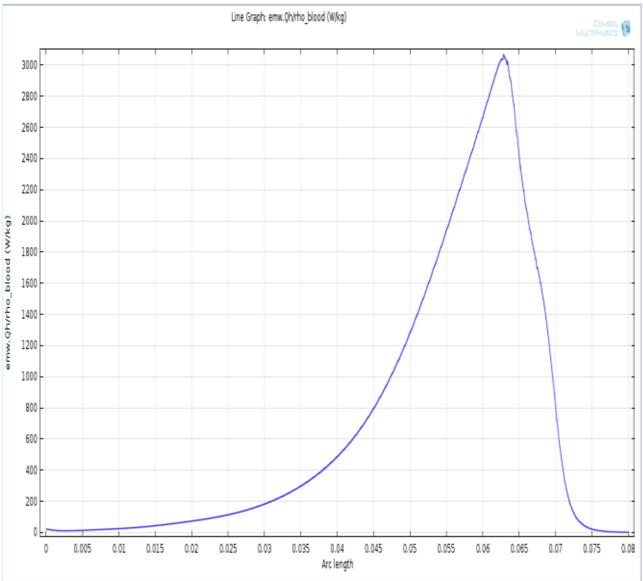

Fig.13 Normalized SAR value of Pancreas Tissue.

6.Conclusion

This work presents the analysis of the axisymrmetric model using thin microwave coaxial antenna in COMSOL multiphysics.The model is rigorously analysed on the basis of mesh statistics,SAR pattern and temperature distribution in tissue generated by the antenna. The models are gives temperature distribution, surface temperature on tissue and power absorbsion in tissue with the variation of different electric, thermal and particular geometry with the coaxial resulting antenna. By steady-state temperature distribution in the tissue for an input microwave power of 10w.We observed that ovary tissue absorved more power and pancreas tissue absorved less power than others.

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