COMSOL CONFERENCE INDIA 2012

Electro Thermal Performance Prediction of Radio Frequency Ablation System for Efficient Cancer Treatment Plan

Gnanasekar V[1] and Raj C Thiagarajan[2]

[1] Perfint Healthcare Pvt. Ltd

[2]ATOA Scientific Technologies Private Limited

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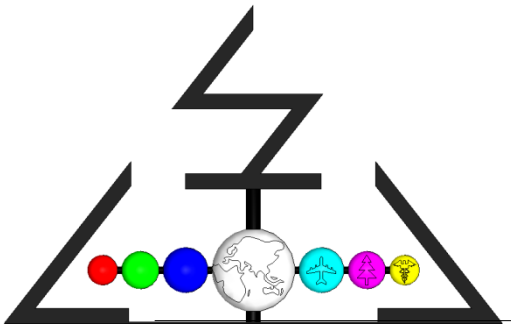
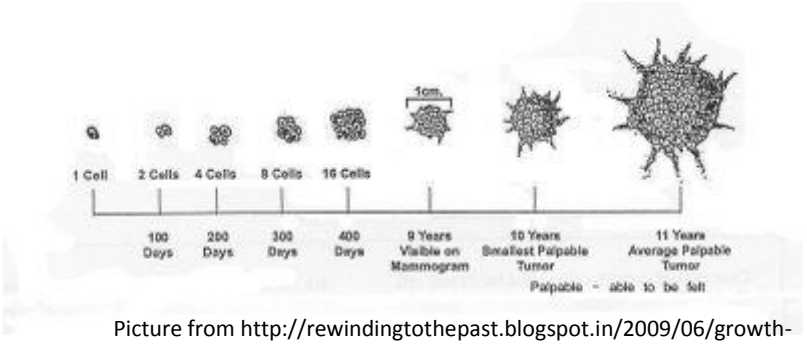


Introduction

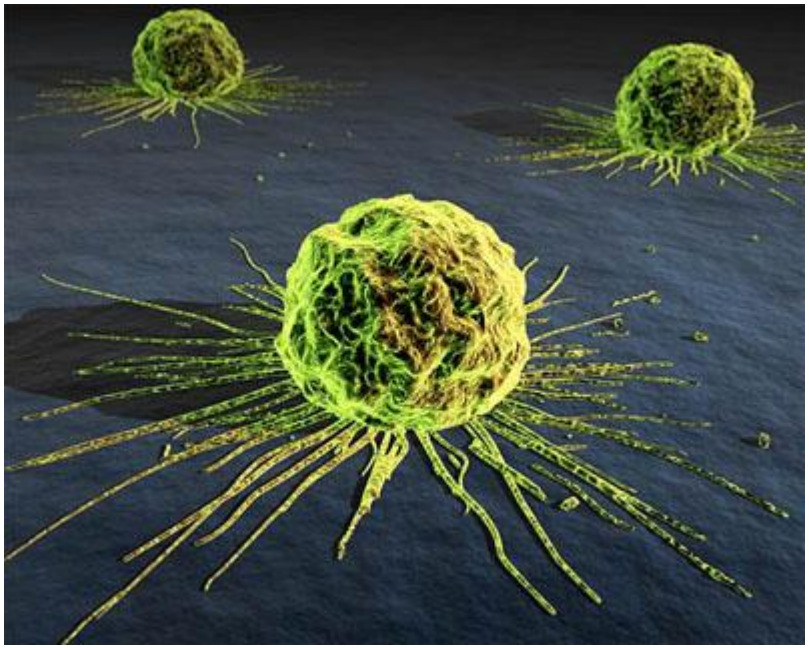
- Cancer causes significant human deaths and is increasing due to increase in life expectancy and lifestyle.



Picture from http://rewindingtothepast.blogspot.in/2009/06/growth-rate-of-cancer-how-long-has-it.html

- Radiofrequency ablation (RFA) is an encouraging procedure for cancer treatment.

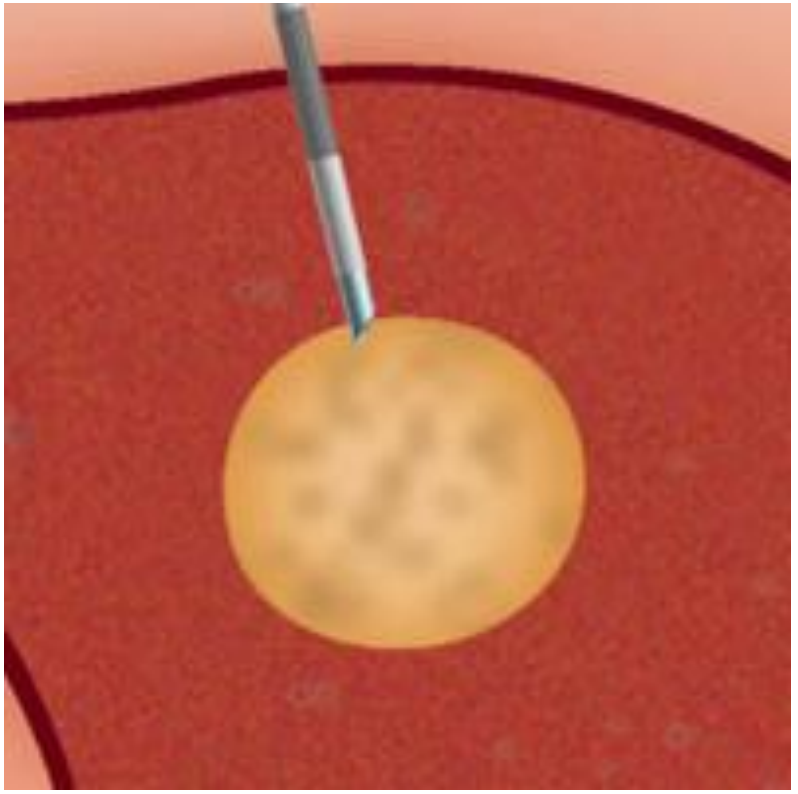
- The objective of this paper is to demonstrate the multiphysics simulation methodology and COMSOL capability for the radio frequency ablation procedure planning and simulation



Picture from http://nursingcrib.com/nursing-notes-reviewer/medical-surgical-nursing/pathophysiology-of-cancer/

RF Ablation

- Radio frequency ablation utilizes ac current and induces heat into the tissue by conversion of electrical energy into thermal energy.
- Temperature control of the tissue is critical for safe and efficient treatment.
- Simulations to plan a safe procedure.



Picture from:
http://www.surgery.usc.edu/divisions/hep/radiofrequencyablation.html

Governing Equation

- The RF electrical conduction of the tissue is governed by the Laplace's equation

$$\frac{\partial^2 \mathrm{V}}{\partial \mathrm{x}^2}+\frac{\partial^2 \mathrm{V}}{\partial \mathrm{y}^2}+\frac{\partial^2 \mathrm{V}}{\partial \mathrm{z}^2}=0$$

- The heat transfer in the tissue is governed by the Bio heat equation

$$\nabla \cdot k\nabla T+\dot{q}+Q_m-Q_p=\rho_t c$$

$$\mathrm{q}=\mathbf{j}\cdot\mathbf{E}=\frac{1}{\sigma}\left[\left(\frac{\partial \mathrm{V}}{\partial \mathrm{x}}\right)^2+\left(\frac{\partial \mathrm{V}}{\partial \mathrm{y}}\right)^2+\left(\frac{\partial \mathrm{V}}{\partial \mathrm{z}}\right)^2\right]$$

- The source term in the bio heat equation is related to the electrical potential for Electro thermal coupling.

which V is electrical potential. Q_m and Q_p represent the metabolic heat generation and the heat loss due to blood perfusion. T, is the temperature, k is, the thermal conductivity.

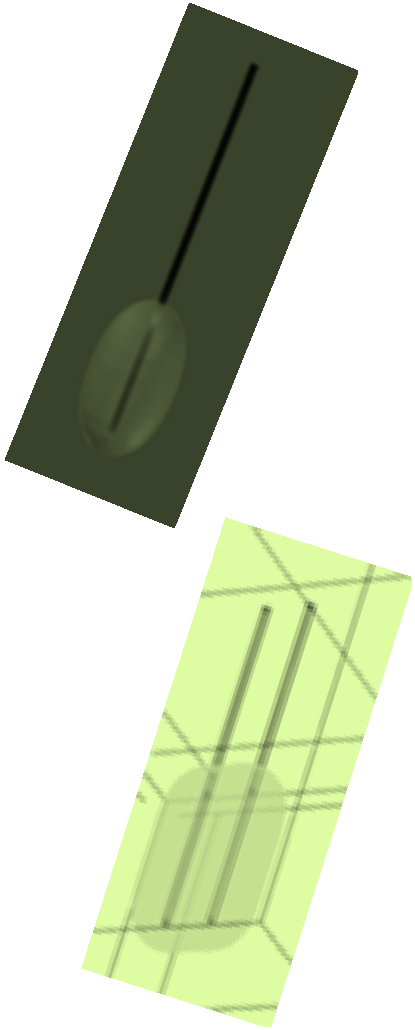
Design and Simulation

- Cool-tip™ RF Electrode Kits, Single model ACT1530 with length of 150mm and an exposure of 30 mm is modeled.
- Liver tissue 3D volume of around 120 mm deep axisymmetric segment was modeled with appropriate boundary conditions.
- The electrode center of the exposure is positioned at the center of the Liver tissue Volume.
- A frequency of 480 kHz at 100 Watts energy output of the electrode is considered.

Picture from http://www.cool-tiprf.com/electrodes.html

DoE Design and Simulation

- A frequency dependent electrical and Transient thermal simulation was performed.
- The single and twin electrode configuration was used to evaluate the heating performance
- An equivalent electrical potential as prescribed by the manufacturers is applied to the probe
- DoE: Input energy, time duration, Angle, Distance between electrode, exposure length



Electro Thermal Properties of Liver

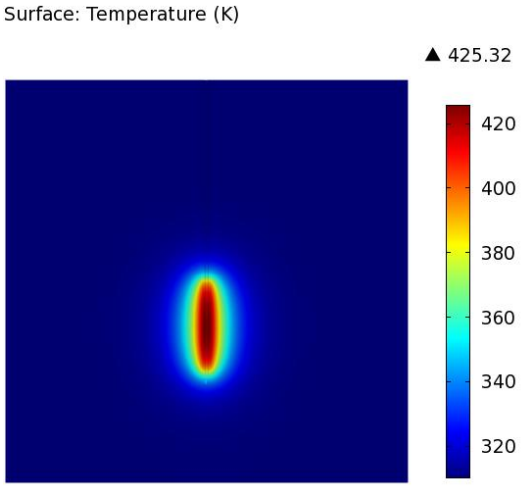
- RF ablation system operates at a frequency range of around 500 kHz.
- The Cool-tip™ RF Ablation Systems operating frequency is 480 kHz.
- The electrical properties of the tissue depend on the composition and structure and are dispersive.

Liver Property	Symbol	Unit	Value
Relative permittivity	εr (500 kHz)	c	2770
Dielectric conductivity	σ (500 kHz)	S/m	0.36
Thermal conductivity	k	W/mK	0.512
Blood perfusion coefficient	ωb	1/s	0.017

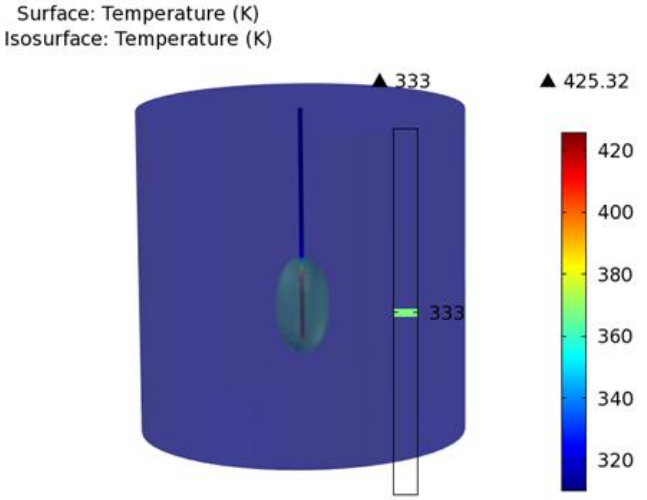
Electro thermal properties of liver Tissue at 500 kHz

Results and Discussion

- The coupled electro thermal performance results are reported
- Input energy, time duration, exposure length were investigated.
- The heating performance results of single probe
- The temperature distribution and electrical potential distribution are highlighted



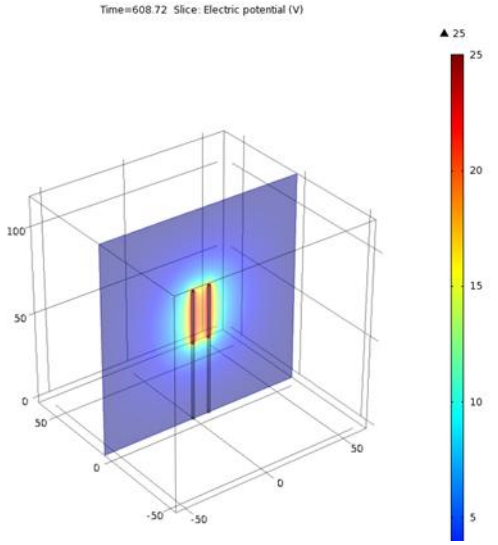
Typical Temperature distribution for a frequency of 480 kHz at 100 W output.



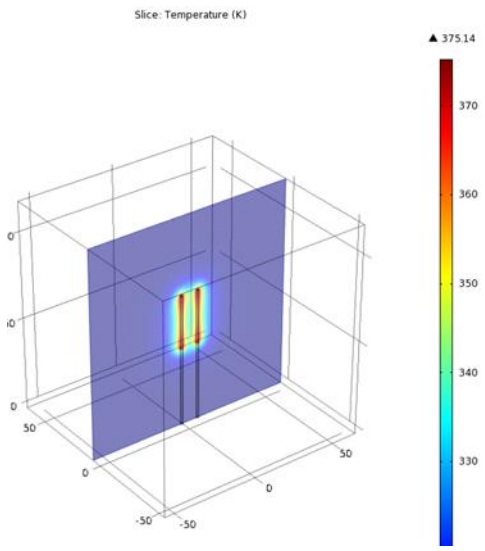
Iso surface distribution for a temp of 333 oK at a frequency of 480 kHz and 100 W output.

Results and Discussion

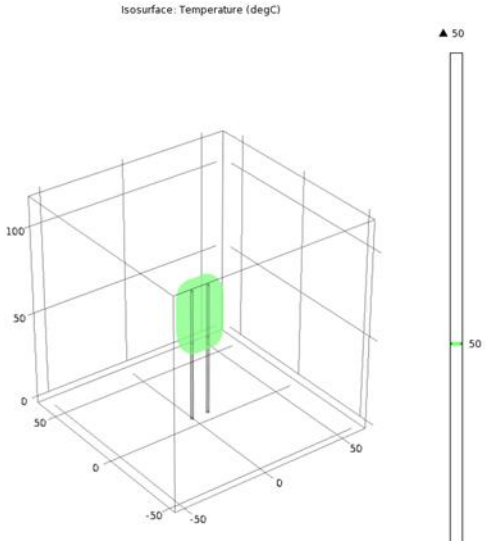
- 3D Model : Twin electrode configuration
- Parameters: Input energy, time duration, Angle, Distance between electrode, exposure length
- Output: Temperature distribution



Typical electrical potential distribution contour plots



Typical temperature distribution contour plots



Typical 50oC Temperature isosurfaces plots

Conclusion

- A brief about Radiofrequency ablation, an interventional technique for cancer treatment was given.
- Coupled electrothermal simulation methodology
- A typical single and twin electrode parallel configuration for cancer ablation was investigated.
- The simulation results showcased the modeling capability and advantages of coupled electrothermal simulation for planning optimal and safe RF ablation