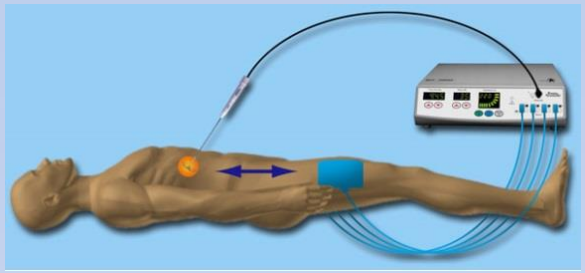
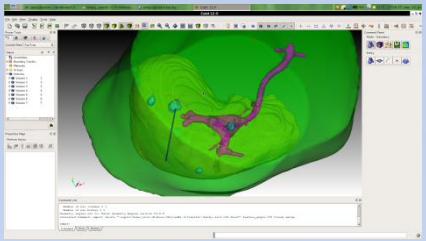
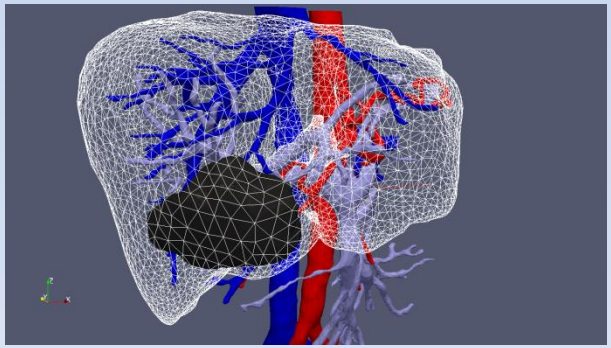
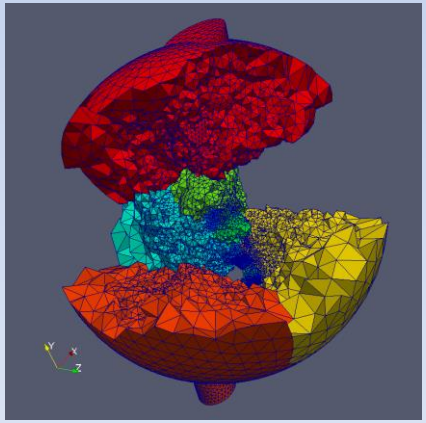
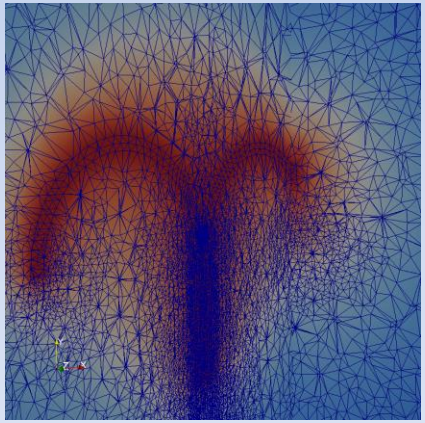
# Supercomputer Simulation of Radio Frequency Hepatic Tumor Ablation









# Mathematical Model

- **The RF ablation destroys the unwanted tissue by heating, arising when the energy dissipated by the electric current flowing through the RF probe is converted to heat.**
- **Bio-heat equation:**

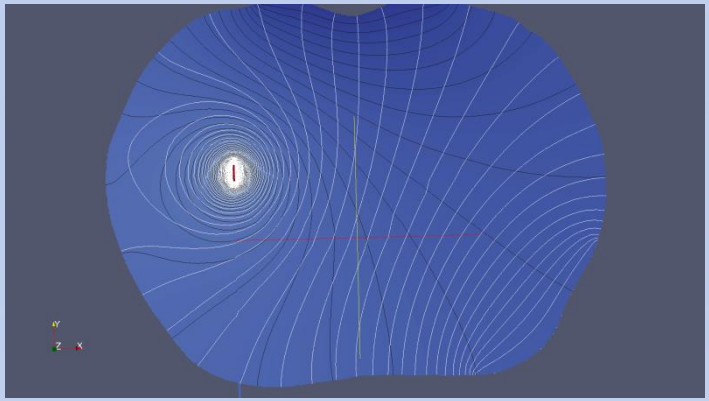
$$\rho c \frac{\partial T}{\partial t} = \nabla \cdot k \nabla T - c_s \nabla \cdot (\mathbf{v}^T) + J \cdot E - h_{bl}(T - T_{bl})$$

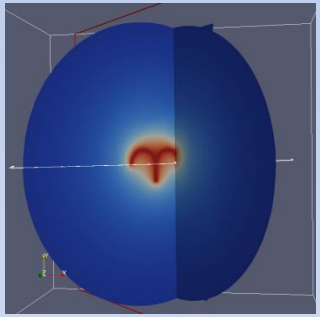
$$\nabla \cdot \sigma \nabla V = 0, \quad E = -\nabla V, \quad J = \sigma(T) E$$

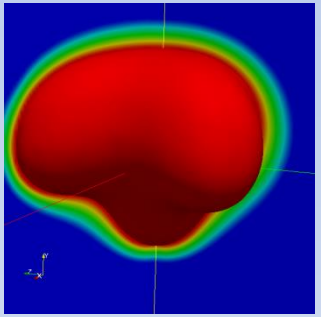
- **Arrhenius equation, is used to assess the level thermal cell necrosis:**

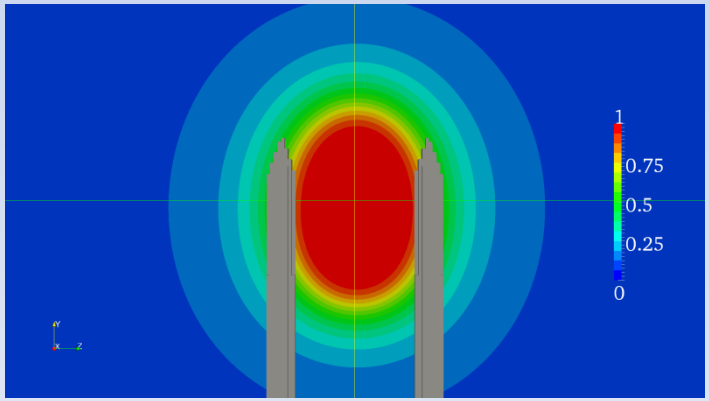
$$\alpha(t) = \frac{1}{e^{\Omega(t)}}$$

$$\Omega(t) = \ln\left(\frac{C(0)}{C(t)}\right) = A \int_0^t e^{-\frac{\Delta E}{RT(\tau)}} d\tau$$

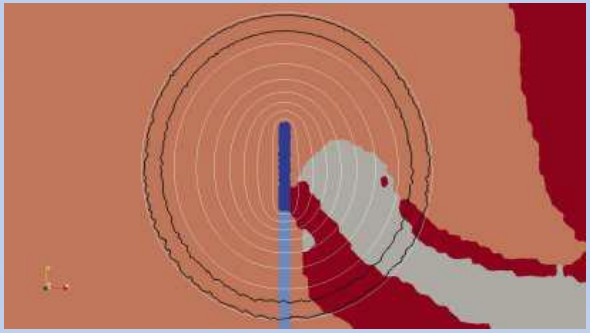
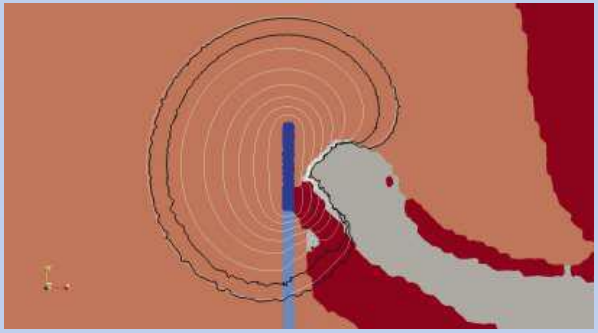
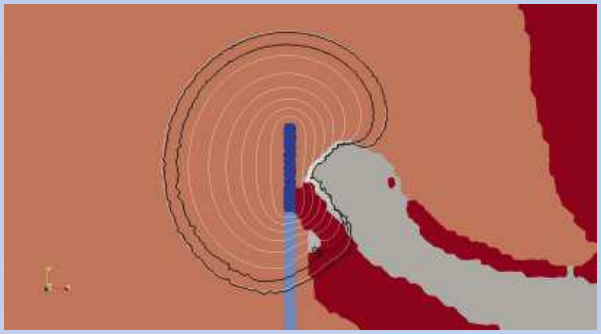








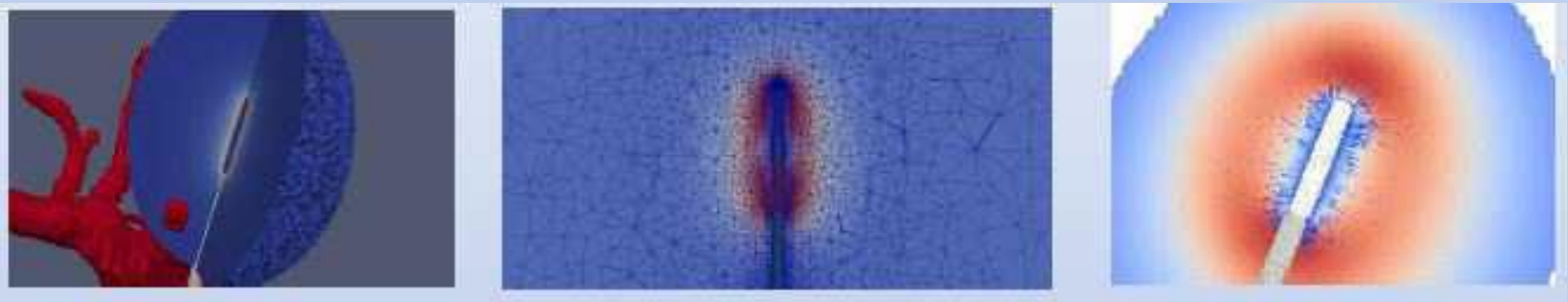
# Impact of Blood Circulation

**Blood circulation is not included (left); Portal vane included (center); Portal vane and capillary network included (right)**

| Test Problem | $V_1[cm^3]$ | Impact | $V_{4.6}[cm^3]$ | Impact |
|---|---|---|---|---|
| Without blood circulation | 20.7 | | 14.0 | |
| Portal vane is included | 10.8 | 1.91 | 6.7 | 2.09 |
| Portal vane and capillary network are included | 7.8 | 2.65 | 5.3 | 2.64 |

# Towards Total Efficiency



| Total Weak Scalability on IBM Blue Gene/P | | | | | | |
|---|---|---|---|---|---|---|
| N | P | Δt[s] | $V_1[cm^3]$ | $V_{4.6}[cm^3]$ | $N_{it}$ | T[s] |
| 2 183 424 | 128 | 5 | 12.857 | 9.102 | 642 | 1 723 |
| 17 467 392 | 1 024 | 1.25 | 12.829 | 9.130 | 1610 | 6 170 |

**A bipolar RF probe is simulated. $V_1$ and $V_{4.6}$ stay for the volume of efficient ablation where the cells are destroyed with a probability of 66% and 99% respectively.**

- **There are 8 times more processors and 4 times larger (DOF) problem at each time step.**
- **Then we have additionally 4 times more time steps but only 3.58 times increase of the parallel time.**
- **This means that the related total efficiency is $E_{total}$ = 111%.**

# Publications


**[1] N. Kosturski, S. Margenov, and Y. Vutov: Calibration of Parameters for Radio-Frequency Ablation Simulation, LNCS 8353 (2014), 611-618**

**[2] N. Kosturski, S. Margenov, Y. Vutov, Computer Simulation of RF Liver Ablation on an MRI Scan Data, AIP Conf. Proc. 1487 (2013), 120-126**

**[3] N. Kosturski, S. Margenov, Y. Vutov, Comparison of Two Techniques for Radio-frequency Hepatic Tumor Ablation through Numerical Simulation, AIP Conf. Proc. 1404 (2011), 412-419**

**[4] N. Kosturski, S. Margenov, Supercomputer Simulation of Radio-Frequency Hepatic Tumor Ablation, AIP Conference Proceedings 1301 (2011), 486-493**



**The presented results are obtained in collaboration with AMET Ltd: http://amet-bg.com/en/**