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UNIVERSITAT POLITÈCNICA DE VALÈNCIA

A modelling study of pulsed radiofrequency for pain relief

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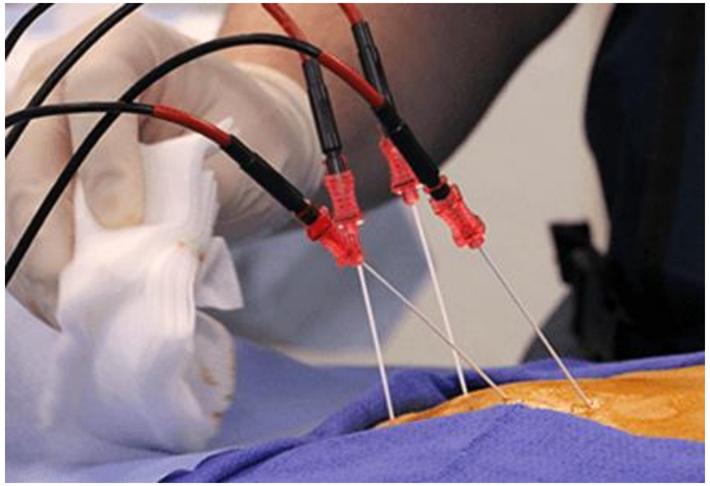
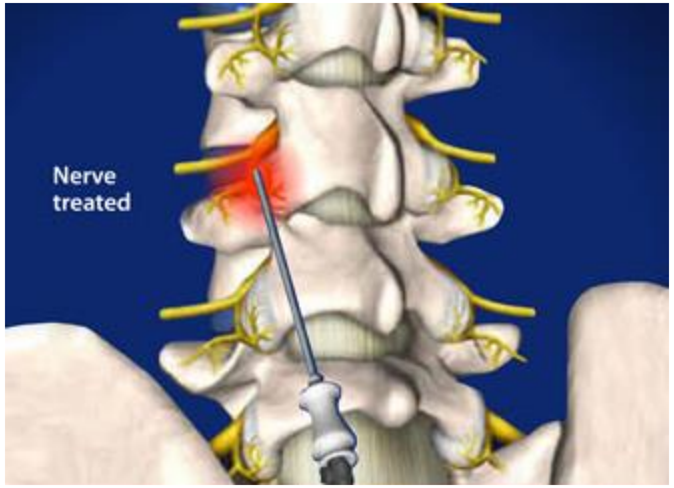
Overview

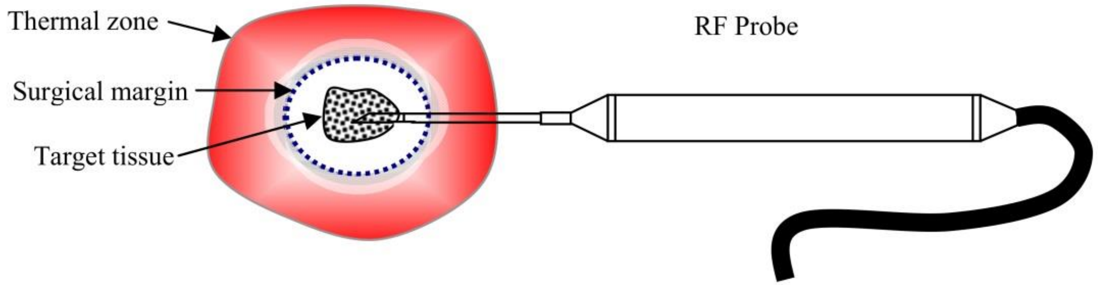
1. THEORY
2. MOTIVATION
3. COMPUTER MODELLING WITH COMSOL
4. RESULTS
5. CONCLUSIONS

Radiofrequency heating

Minimally invasive technique for long-term pain relief in peripheral nerve injury



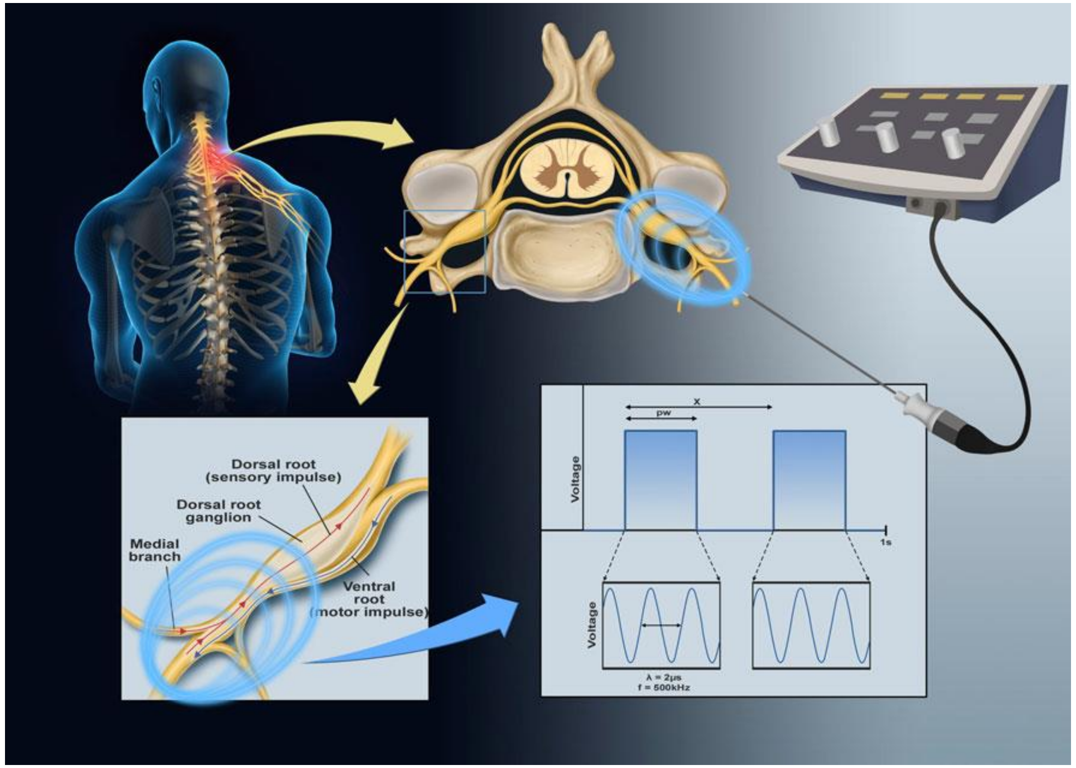




Pulsed radiofrequency (PRF)

RFA	PRF
Heating due to an electro-mechanical friction	**Neuromodulation** through electric field
⇩	⇩
Neurotomy	**Analgesic method**

- Short, high – voltage pulses with high frequency current
- Reduces thermal lesion restricting temperatures to 42ºC

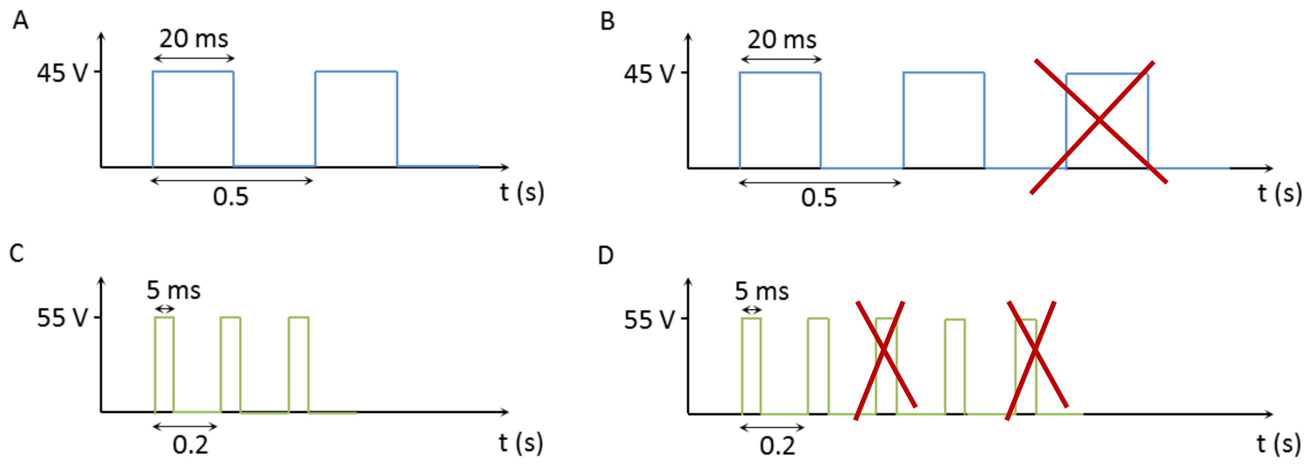


Chua et. al., 2011

Pulse protocols for PRF

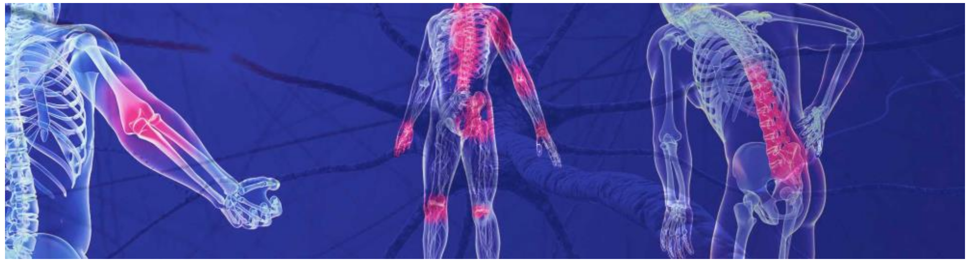
	A	B	C	D
Pulse duration [ms]	20	20	5	5
Repetition frequency [Hz]	2	2	5	5
Voltage [V]	45	45	55	55
Temperature controller (TC)	-	+	-	+

Comparable electric dose



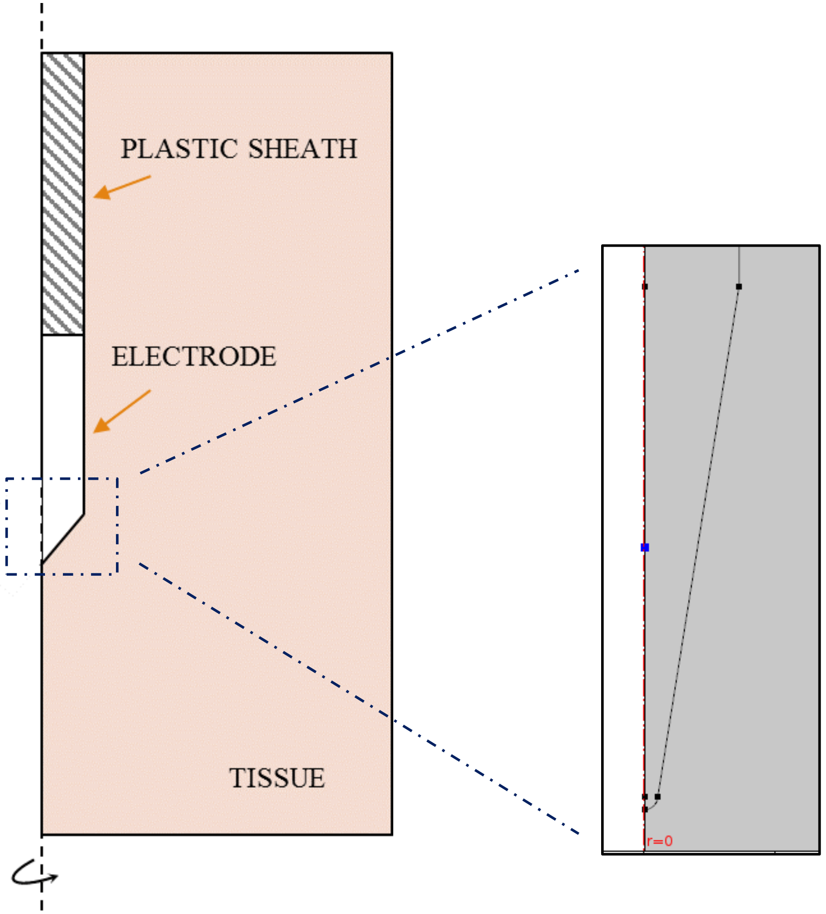
Motivation

- Computational validation of two different pulse protocols for pulsed radiofrequency used in clinical pain management
- Analysis of thermal and electric performance in function of pulse characteristics
- Assessment of temperature control on electric effect in tissue

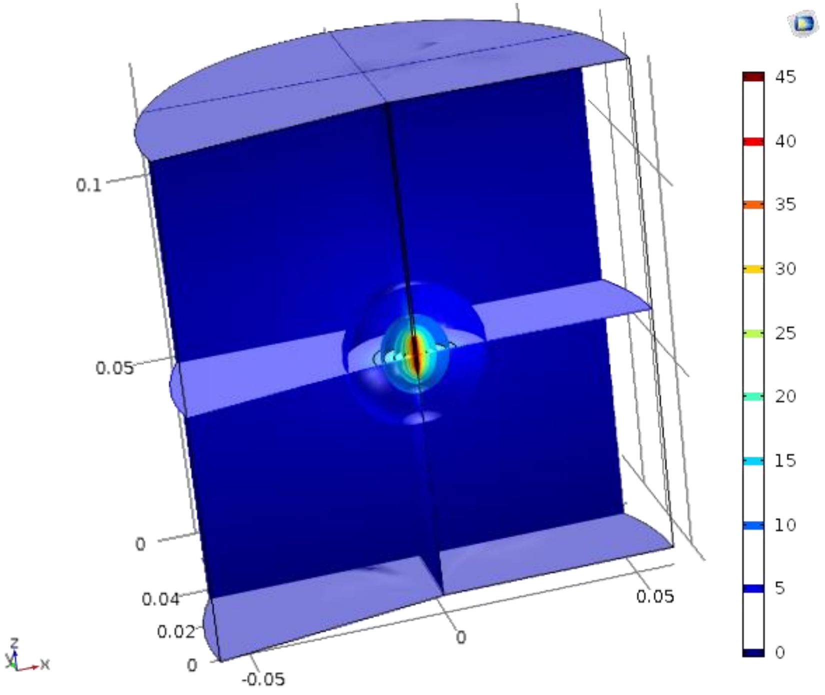


COMSOL – model geometry

2D model



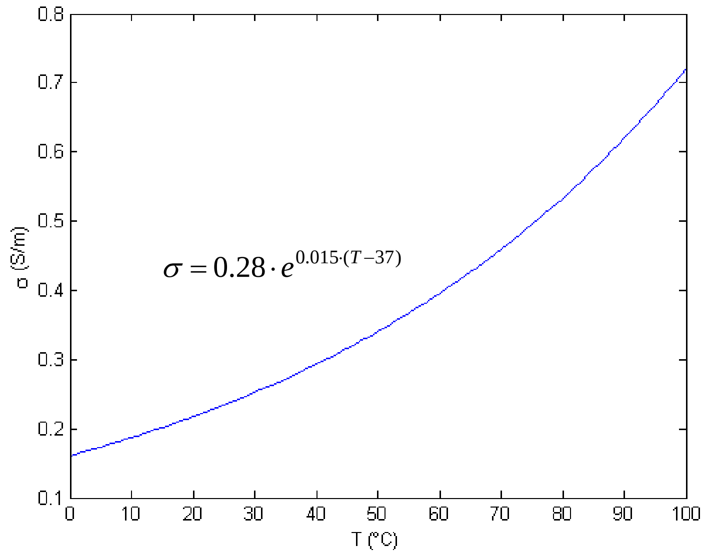
2D extruded model



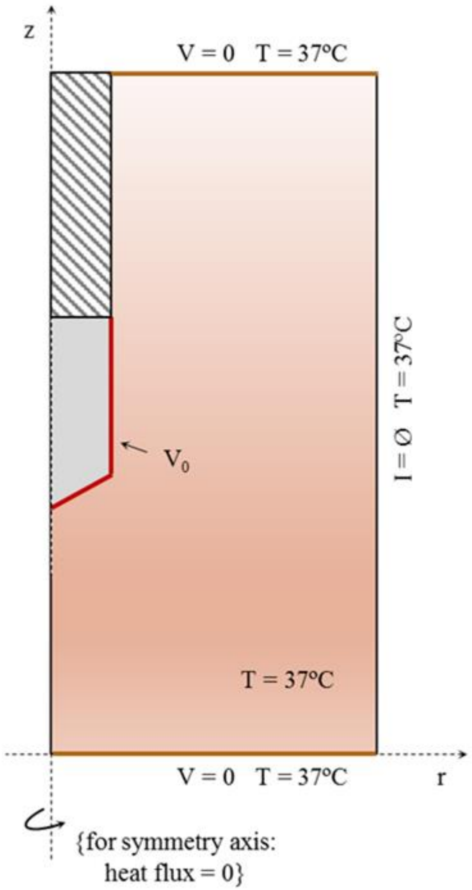
COMSOL – model assumptions

Material	**σ** *S/m*	**k** *W/(m·K)*	**ρ** *kg/m³*	**c** *J/(kg·K)*
Tissue	0.28	0.49	1090	3421
Plastic	10^5	0.026	70	1045
Electrode	7.4×10^5	15	8×10^3	480

- Homogeneous tissue
- Constant thermal conductivity, *k*
- ***Temperature dependent electrical conductivity, σ***



COMSOL – coupled physics



Heaviside function: ***flc2hs****(T, scale)*

Electric Problem

$$\nabla \cdot (\sigma(T) \nabla V) = 0$$

$$\boldsymbol{E} = -\nabla V$$

$$q = \sigma(T) |\boldsymbol{E}|^2$$

Thermal Problem

$$\rho c \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + q + Q_P$$

$$Q_P = -\beta \omega \rho c (T_a - T)$$

$$\beta = \begin{cases} 1, & \Omega \le 4.6 \\ 0, & \Omega > 4.6 \end{cases}$$

Pulse protocols for PRF

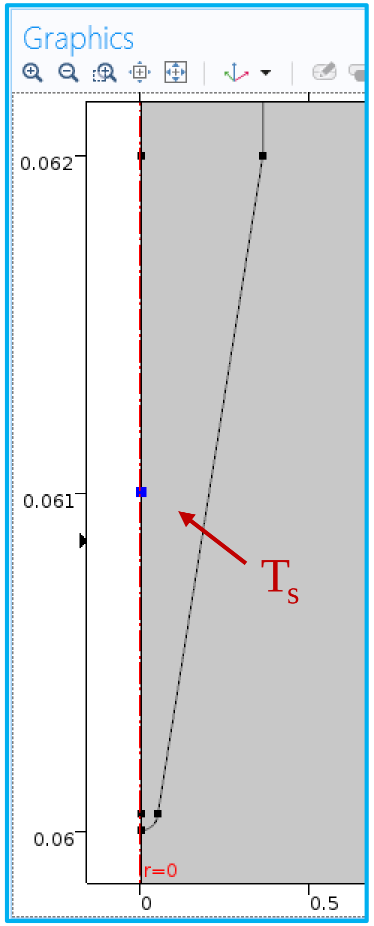
Thermal damage

$$\Omega(t) = \int_0^{\tau} A e^{\frac{-\Delta E}{RT}} ds$$

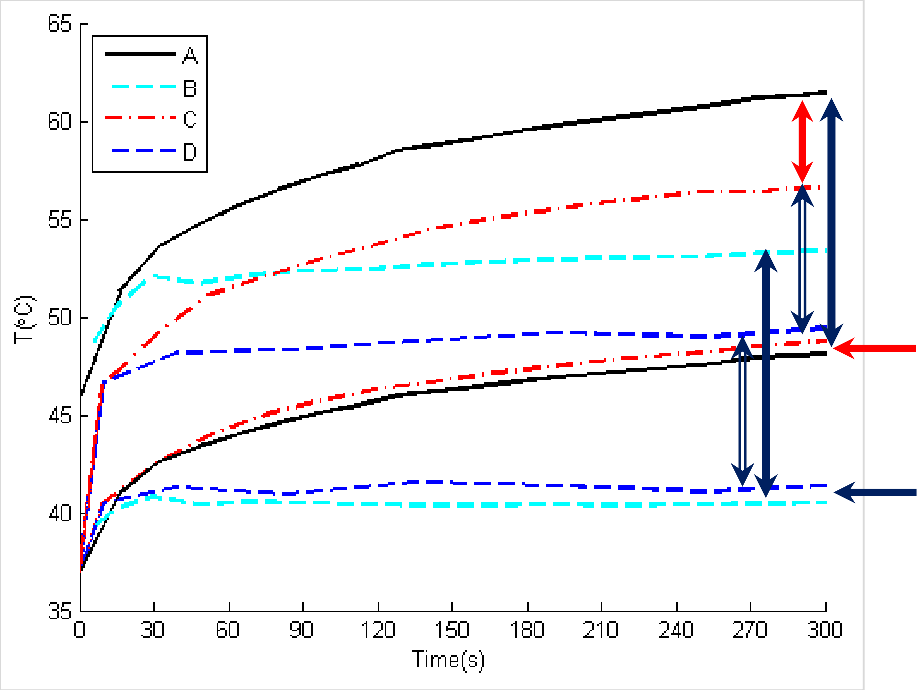
Temperature controller

$$v(t_i) = \alpha v_i$$

$$\alpha = \begin{cases} 1, & T_S < 42°C \\ 0, & T_s \geq 42°C \end{cases}$$



Thermal performance



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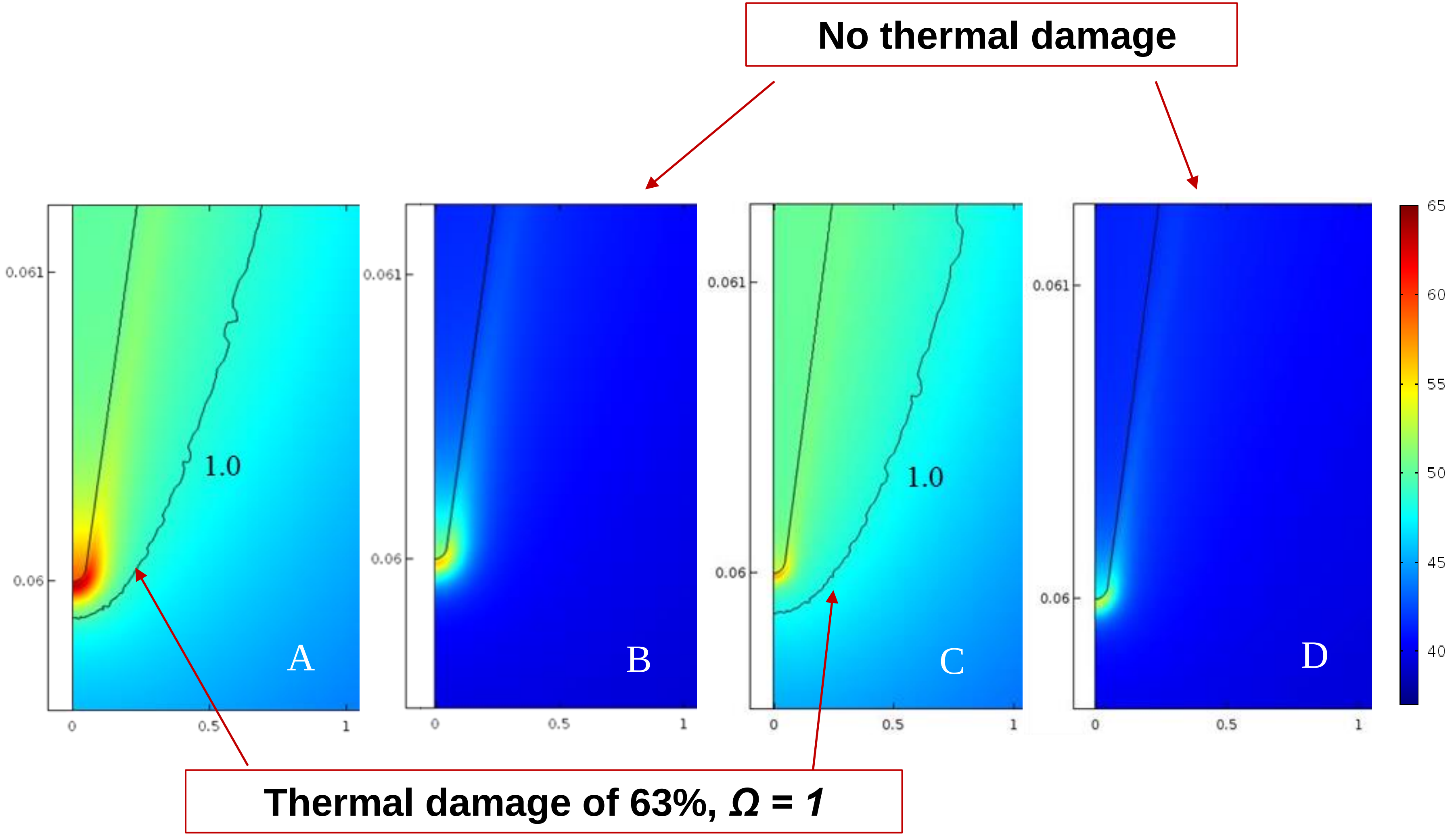
No temperature controller

- Maximal temperature reduced by 5ºC
- No change in minimal temperature distribution (~49ºC)

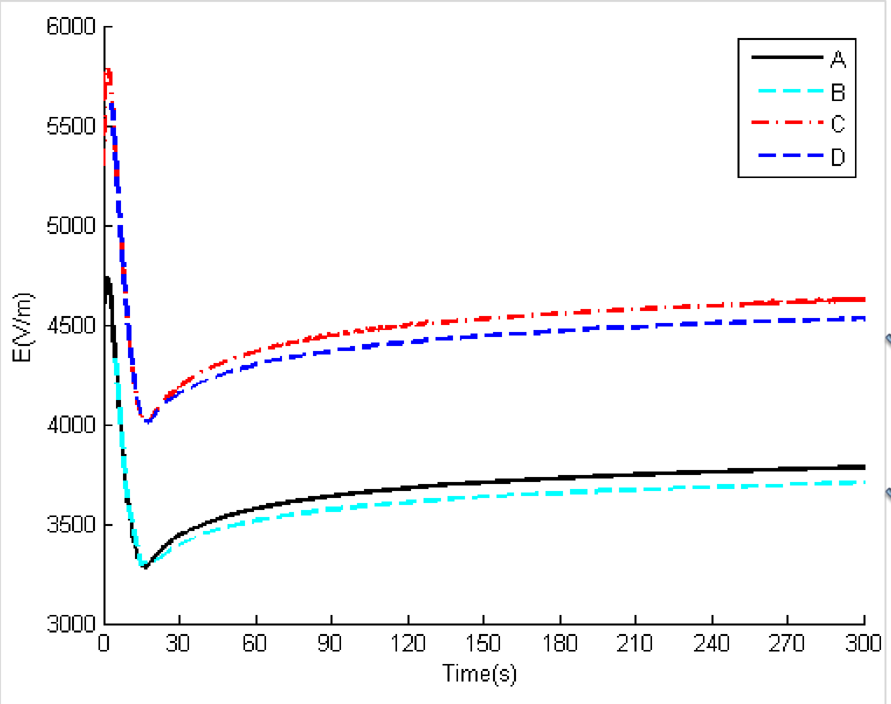
Temperature controller

- Minimal temperatures maintained at ~42ºC
- Temperature range unchanged

Thermal damage



Electrical performance



N° pulses reduced

↓53.8%

↓57.5%

- Higher magnitude of electric field for higher voltaje independently on temperature control

- No change in electric field magnitude in the presence of temperature controller

Conclusions

- Determination of changing material properties ($\sigma(T)$) and other parameters by means of specific functions (*flc2hs*)
- Pulse of shorter duration implies tissue temperature reduction and benefits the electric effect in tissue
- Temperature controller is needed to avoid the risk of thermal lesion

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