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COMSOL CONFERENCE 2017 BOSTON

Multiphysics Modeling of a Minimally Invasive Tissue Ablation Methodology

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Radiofrequency tissue ablation

- Common therapeutic procedure to destroy diseased tissue
- Goal: sufficiently heat only the diseased region
- Typically necrosis achieved at temperatures above 50°C

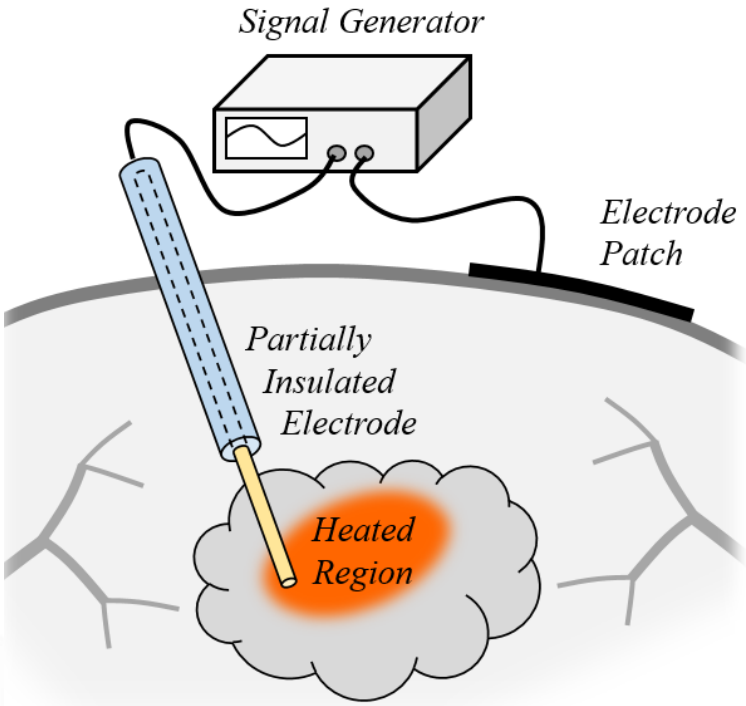

Image source:
www.comsol.com/blogs/study-radiofrequency-tissue-ablation-using-simulation/
Walter Frei – Jan 20, 2016

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Device inserted into heart and pressed against vessel wall

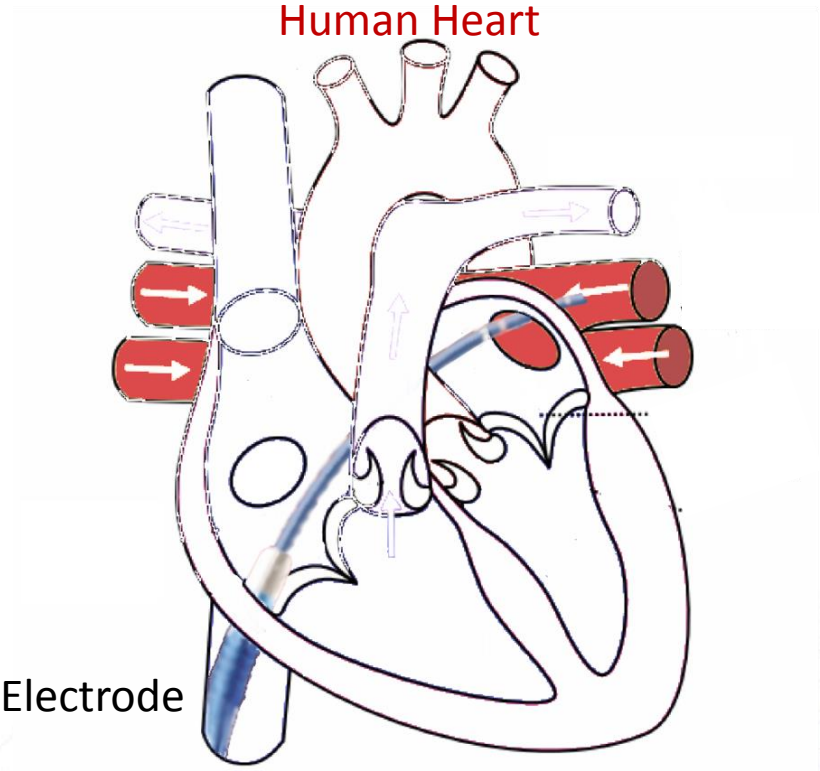
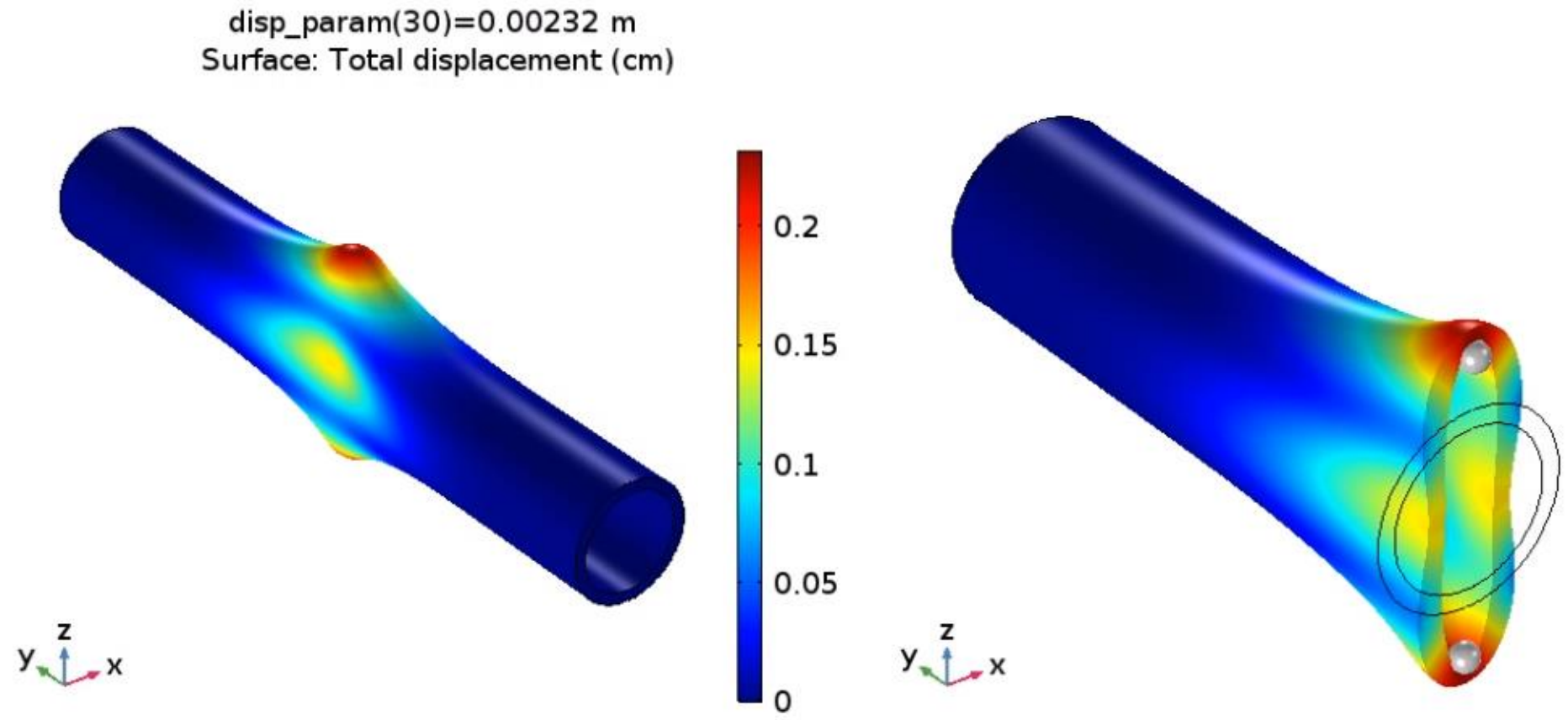


Image source: Wikipedia

Deformation



Tissue ablation – Simulation challenges

- Multiphysics
- Intimate couplings
- Large tissue deformations
  - Geometric non-linearity
  - Meshing of collapsing volumes
- Contact
  - Mechanical
  - Electrical

Multiphysics couplings

- **Solid mechanics**
  - Large displacements
  - Electrode/tissue
- **Laminar flow**
- **Electric currents**
- **Heat transfer**
  - Convection
  - Perfusion (bio heat equation)
  - Conduction

Deformed geometry

Joule heating

Conjugate heat transfer in blood flow

MODEL DEVELOPMENT

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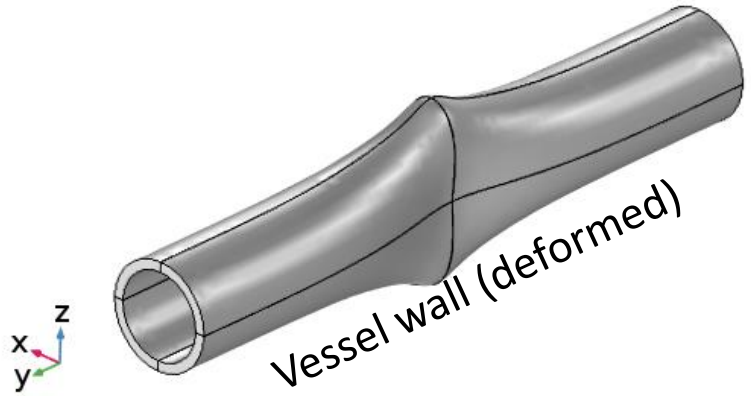
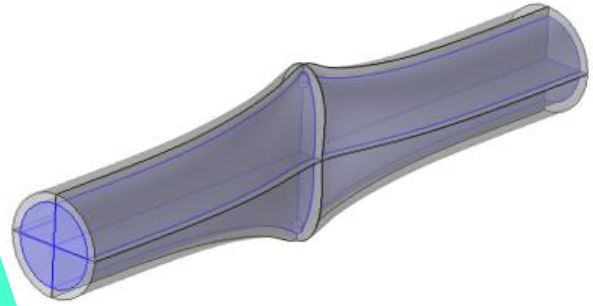
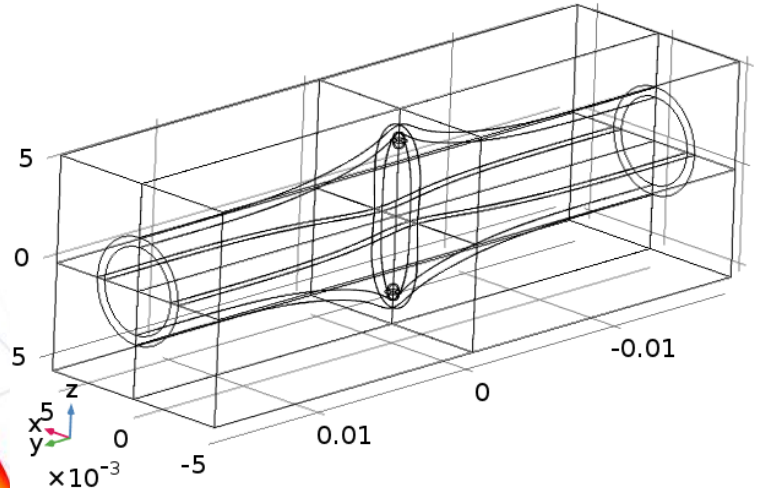
Geometry

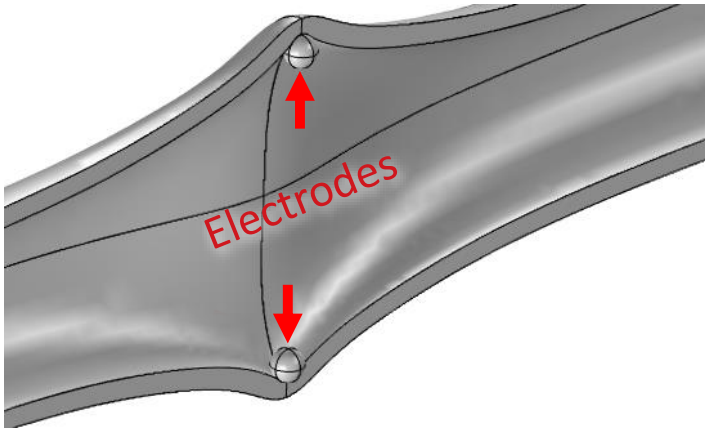
- Blood vessel
  - vessel wall
  - blood
- Electrodes
- Bulk tissue



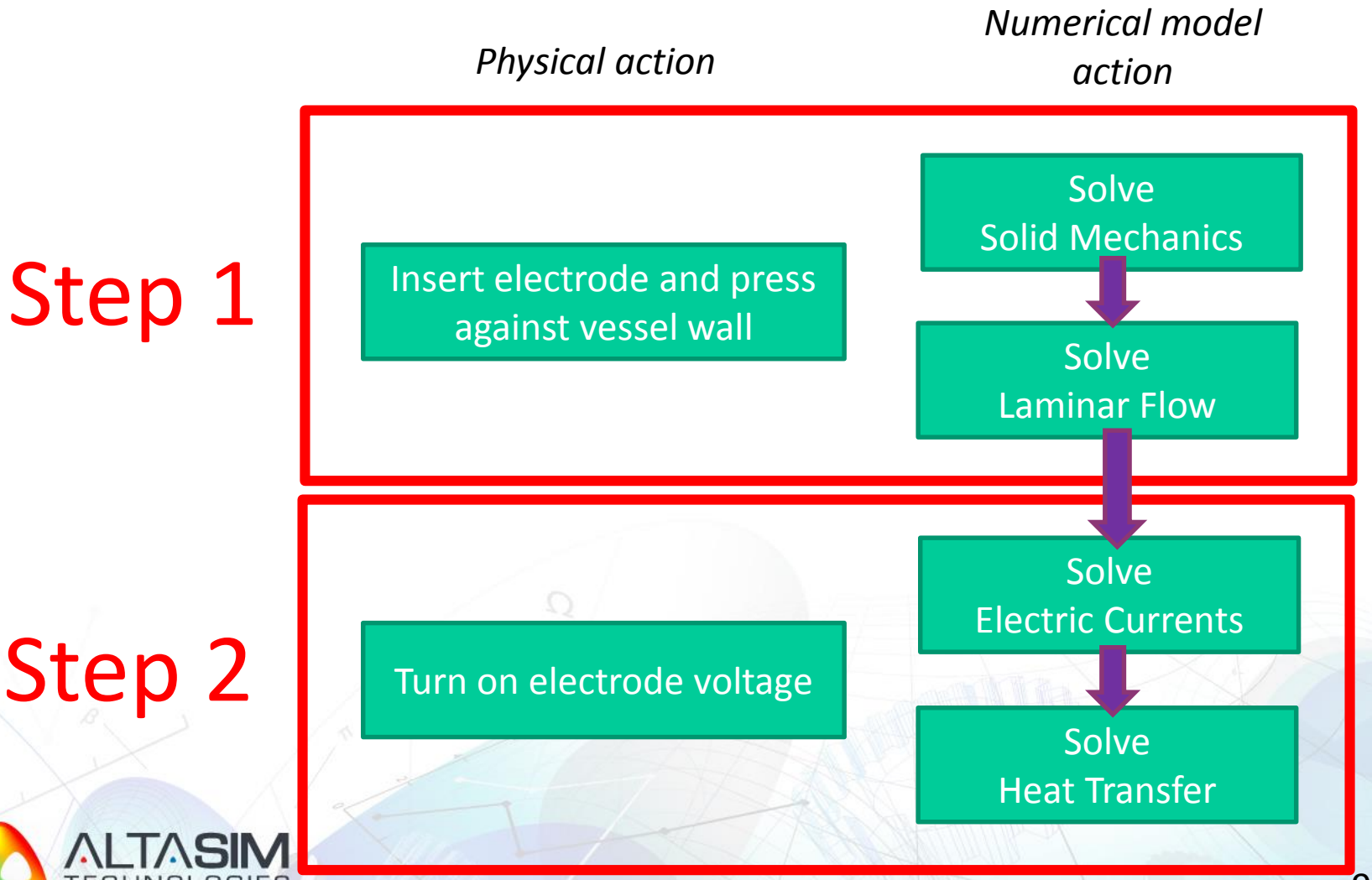


Blood inlet = 60 cm/s





Multiphysics implementation



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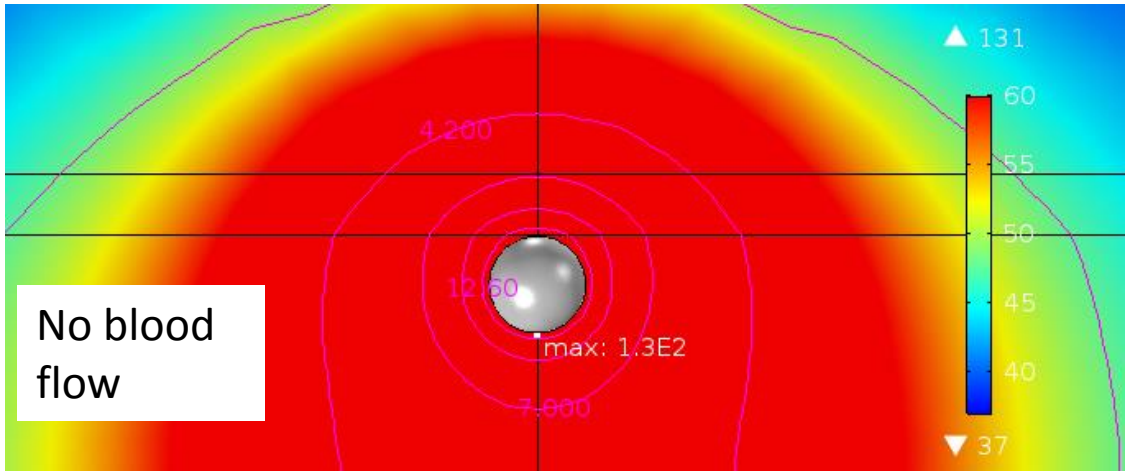
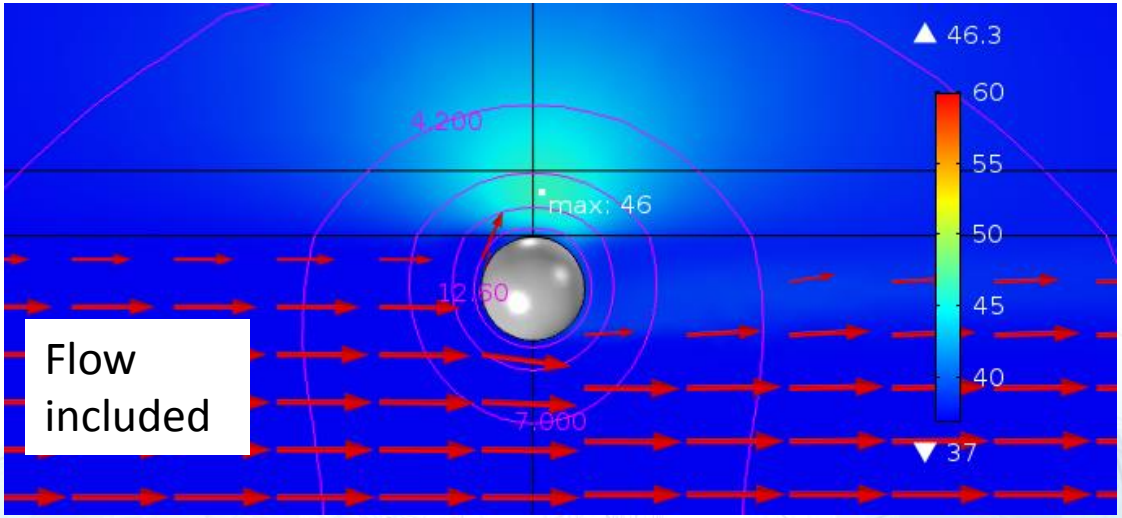
RESULTS

Heating



No blood flow



Flow included

Note: Temperature solution highly dependent on convection into blood flow

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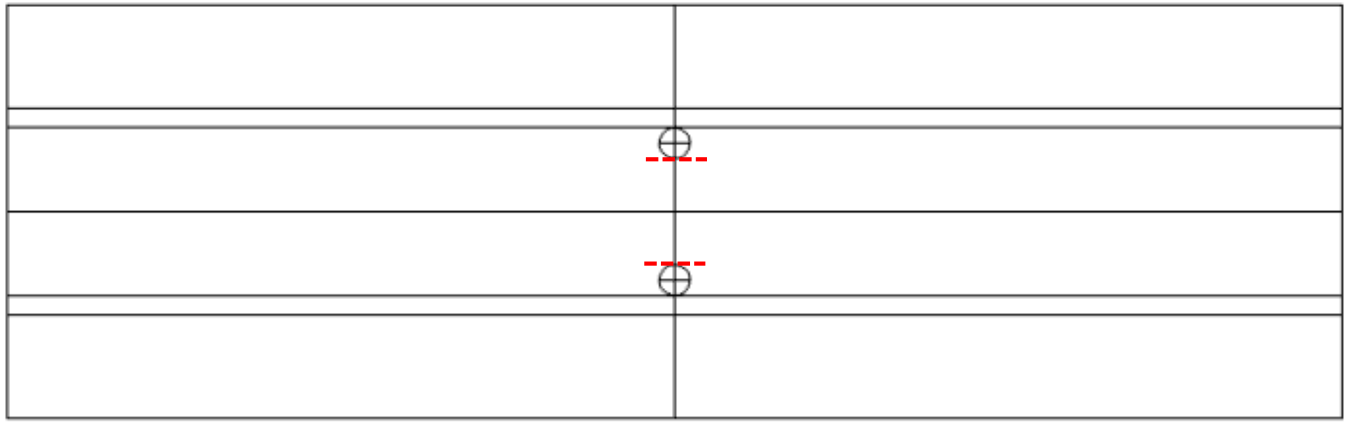
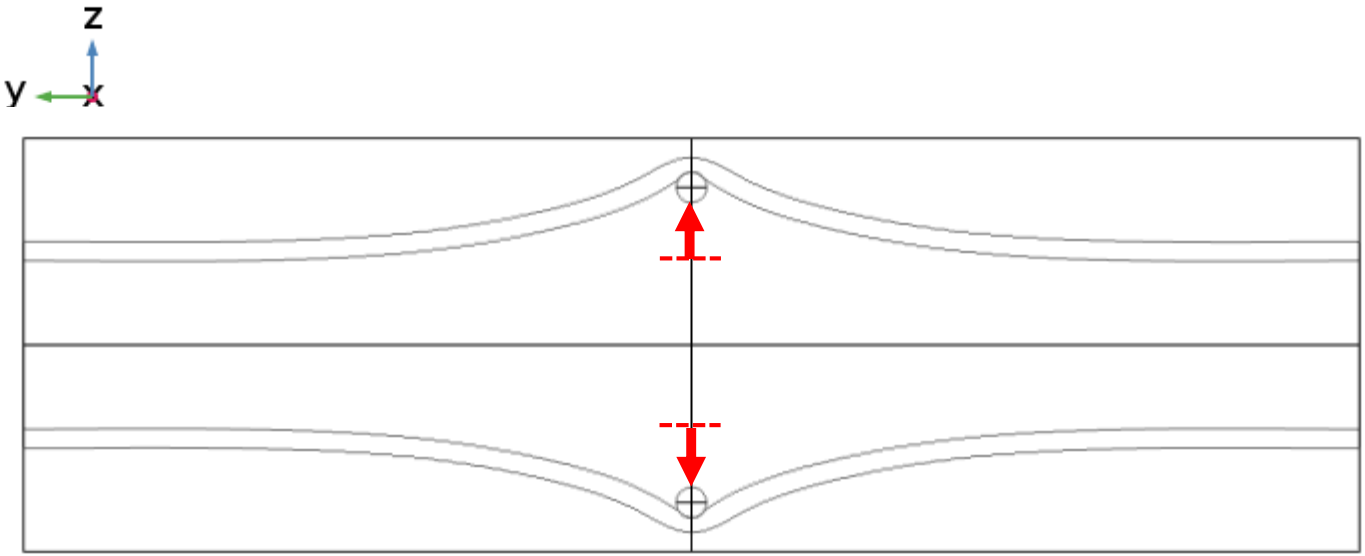
Deformation

Undeformed

Sphere displacement = 0 mm





Deformed

Sphere displacement = 2.32 mm

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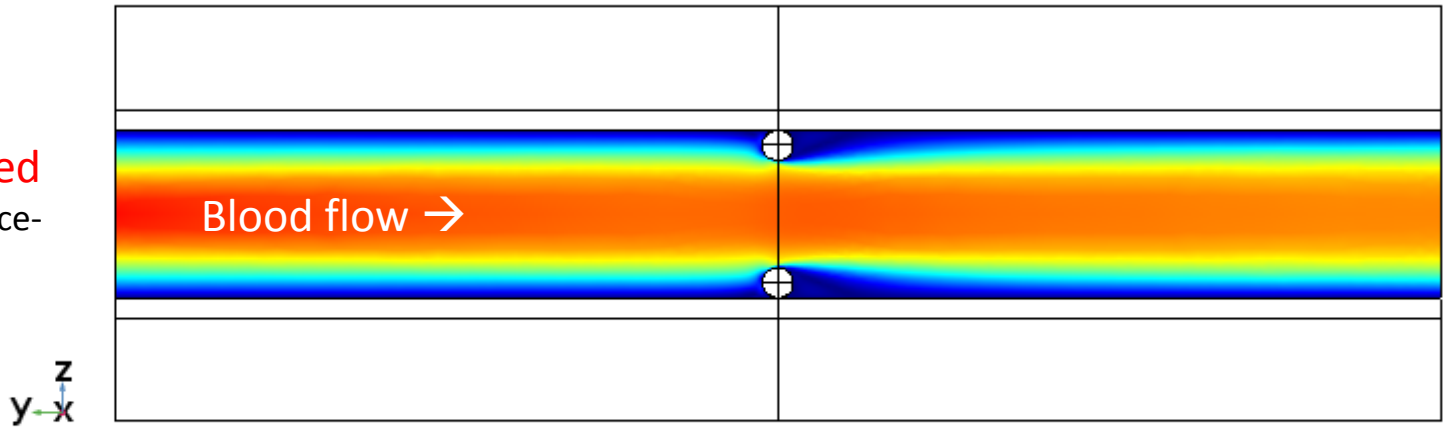
Flow

Blood velocity magnitude (m/s)

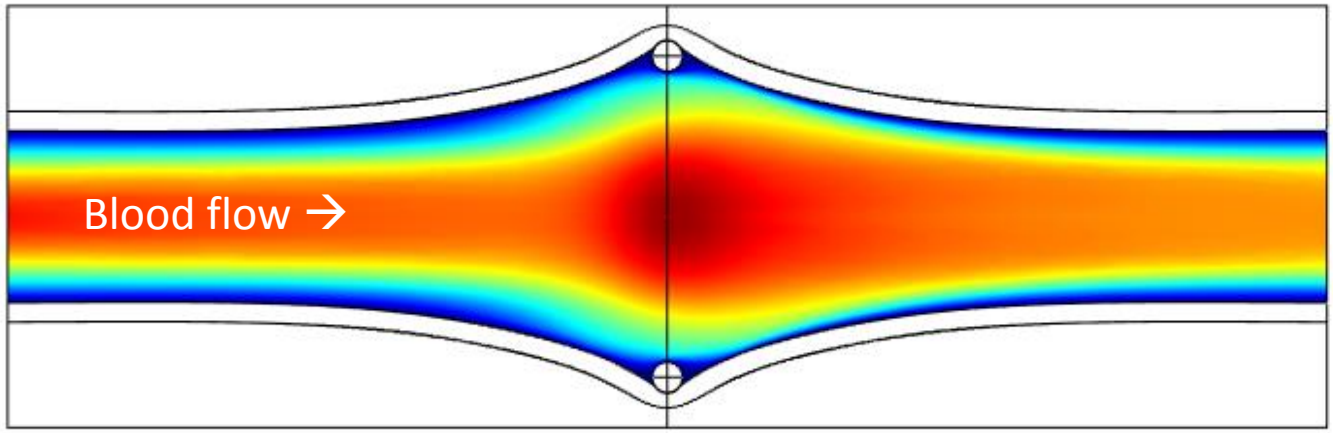
Undeformed

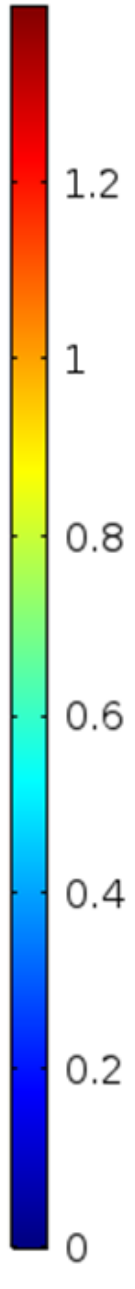
Sphere displacement = 0 mm



Deformed

Sphere displacement = 2.32 mm





Blood velocity magnitude (m/s)

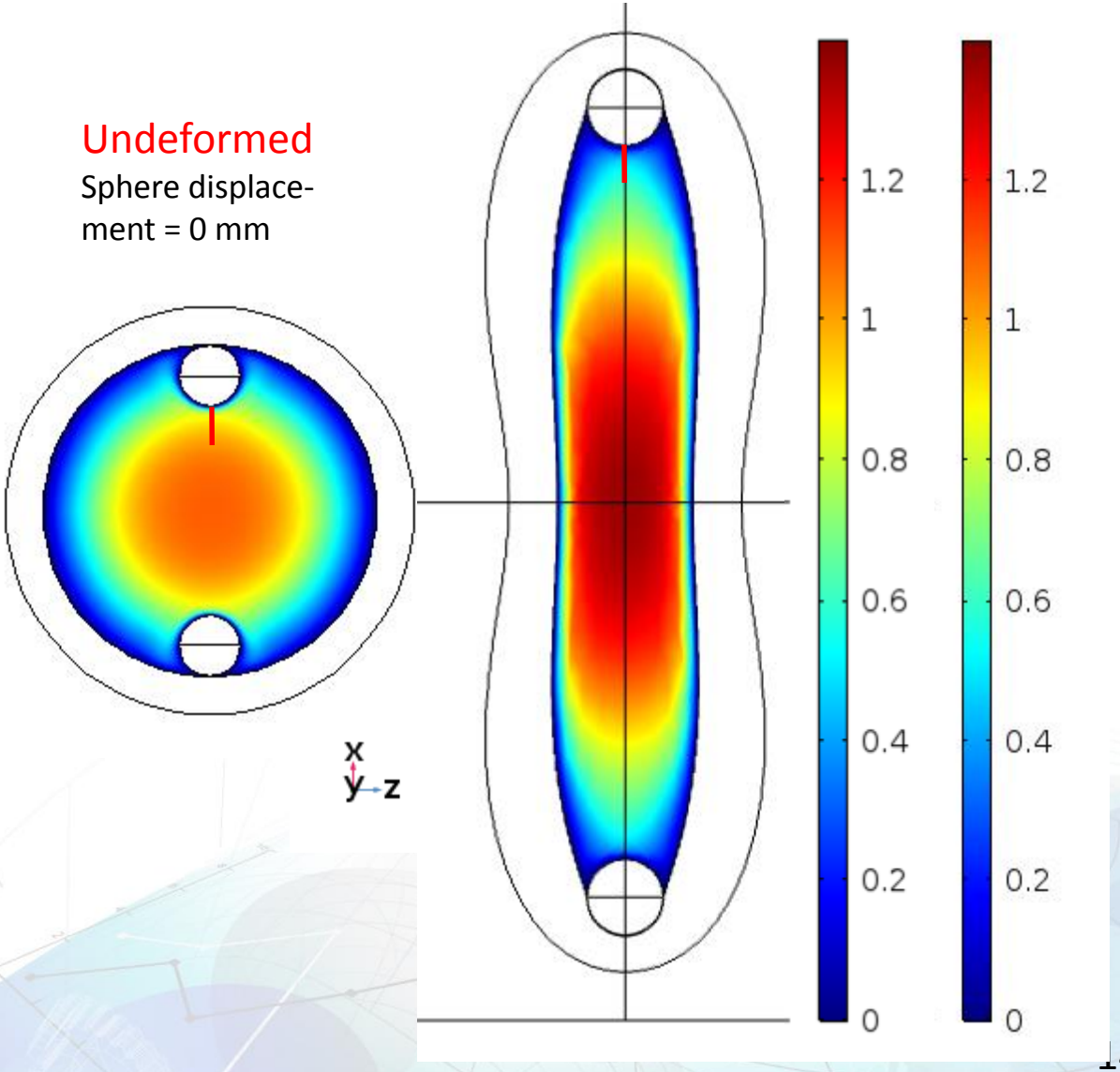
Flow

Deformed

Sphere displacement = 2.32 mm

Undeformed

Sphere displacement = 0 mm



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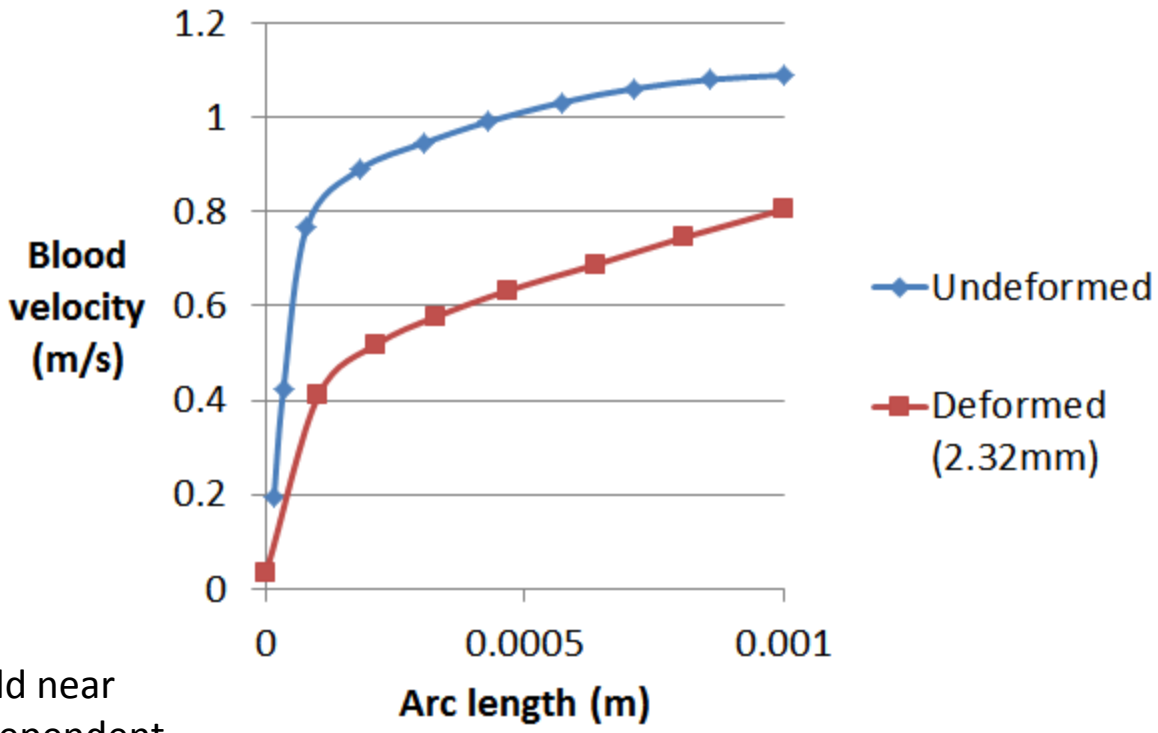
Flow



Note: Velocity field near electrode highly dependent on deformed shape

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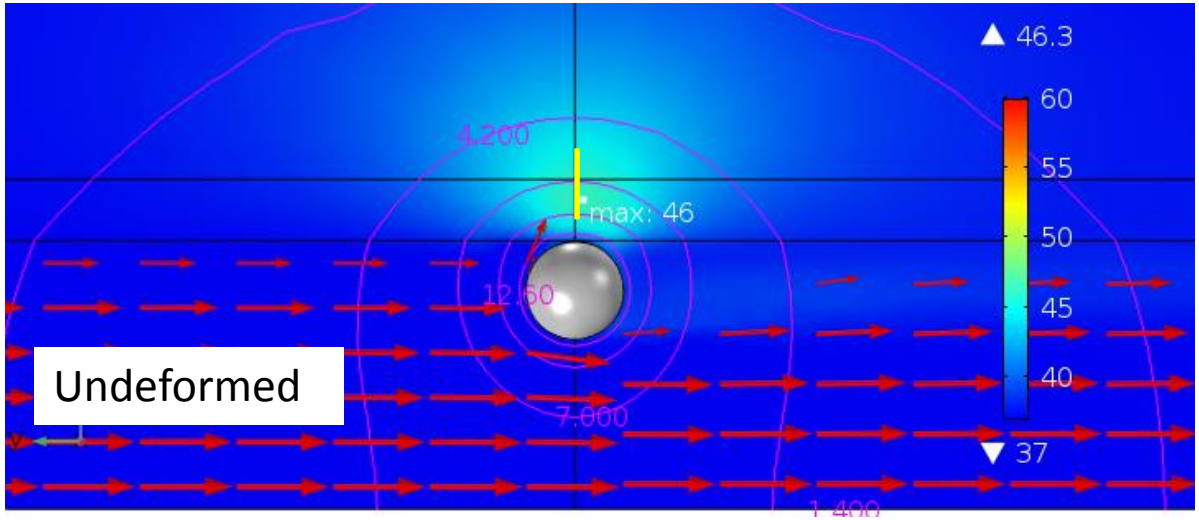
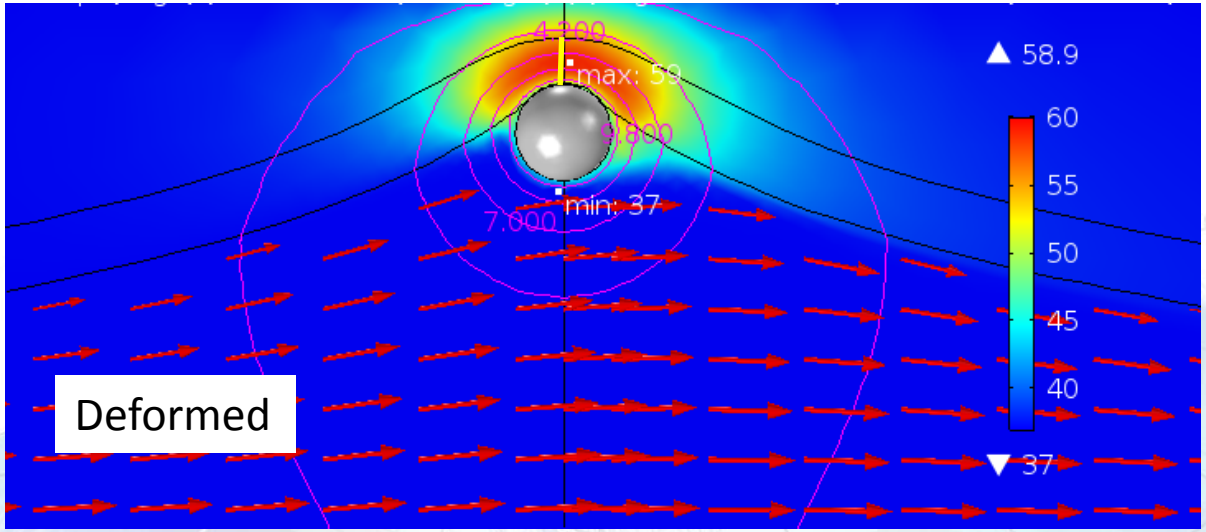
Heating

Undeformed
Sphere displacement = 0 mm



Deformed
Sphere displacement = 2.32 mm



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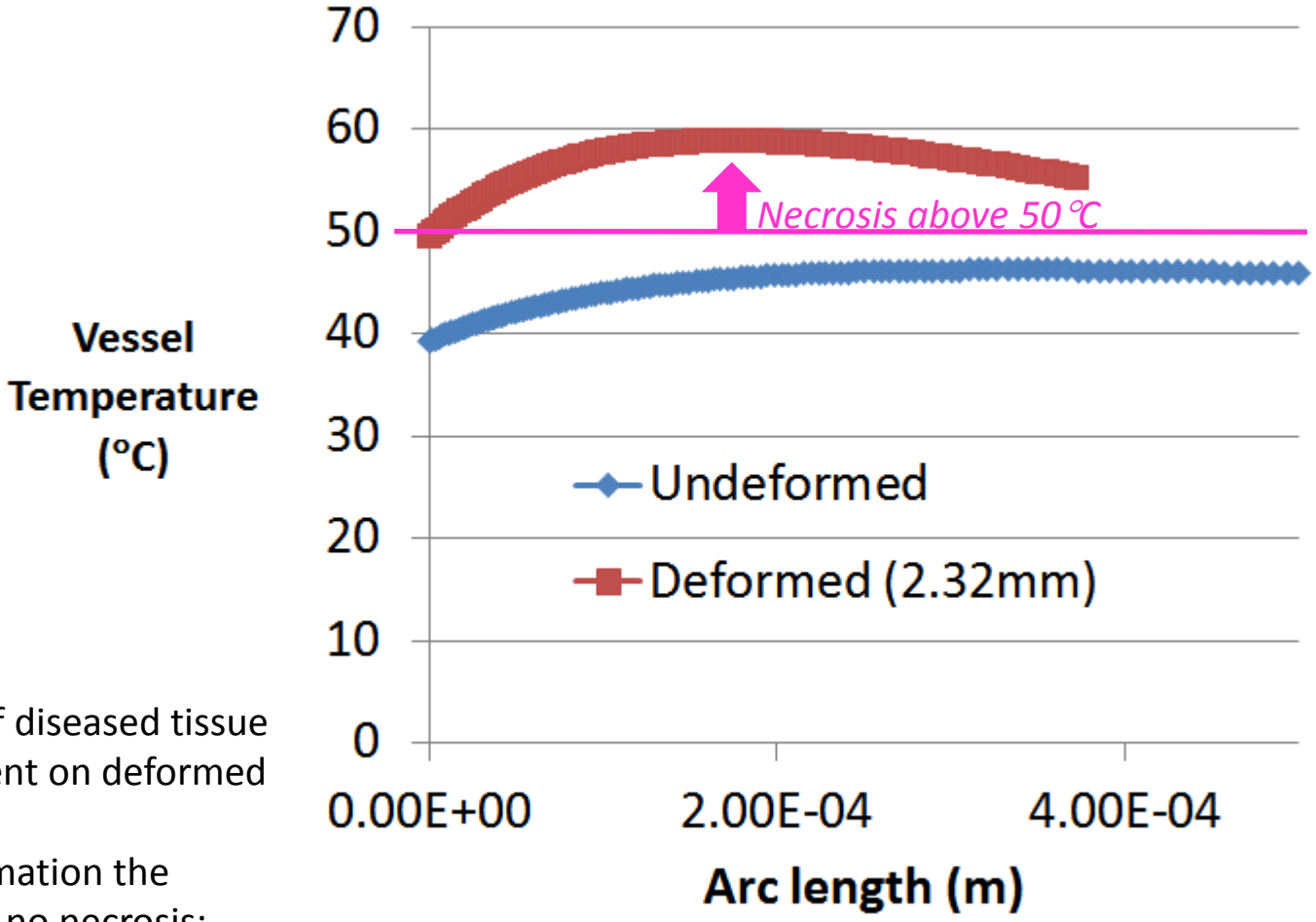
Heating



Note:

1) Temperature of diseased tissue highly dependent on deformed shape
2) Without deformation the model predicts no necrosis; with deformation complete necrosis through the thickness

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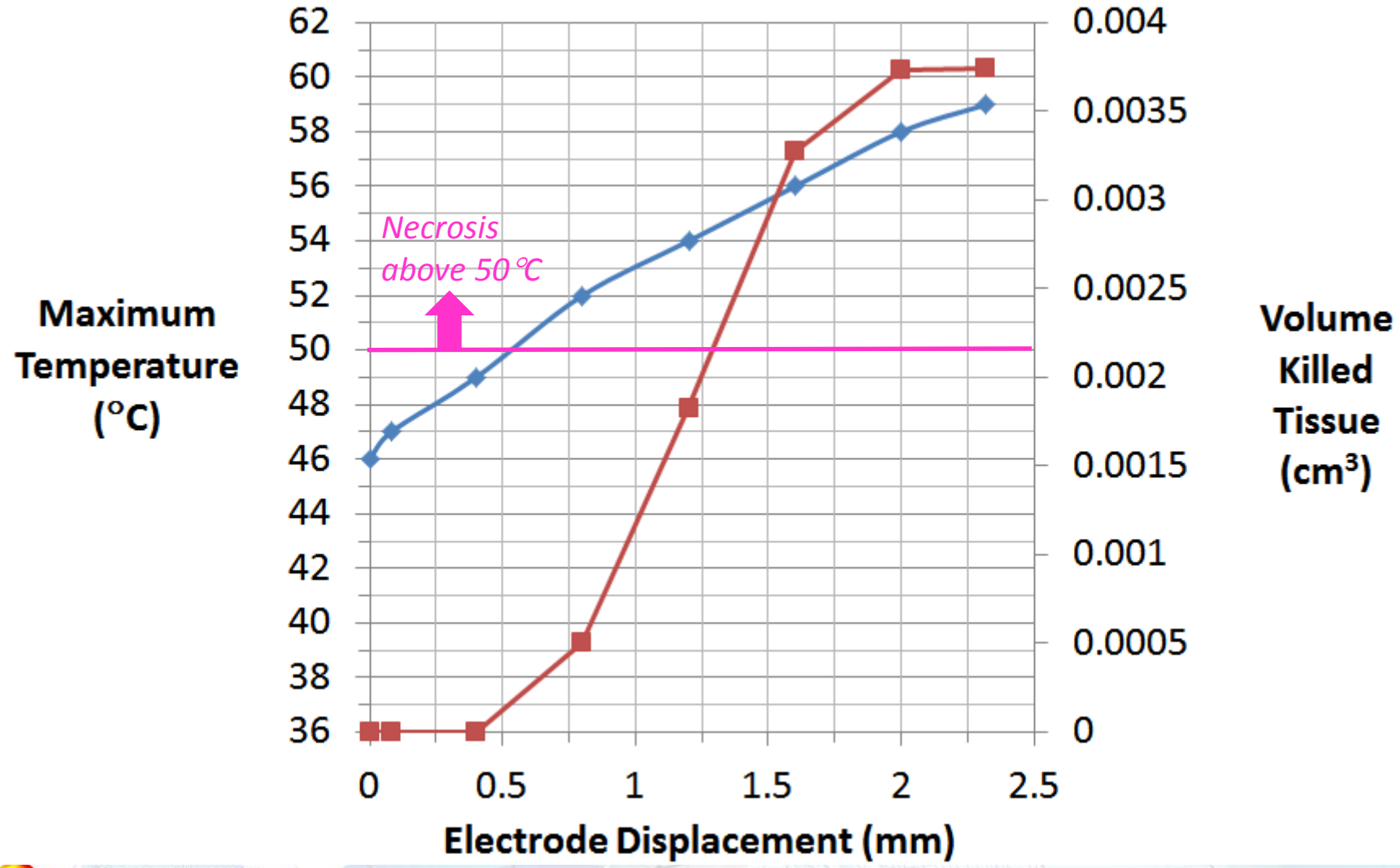
Heating



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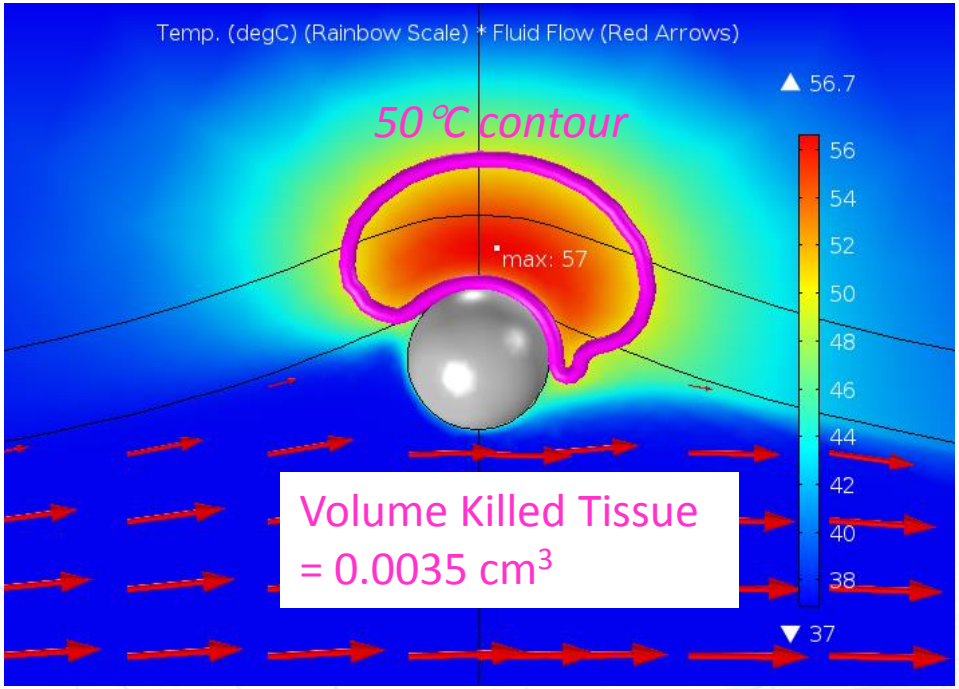
Heating

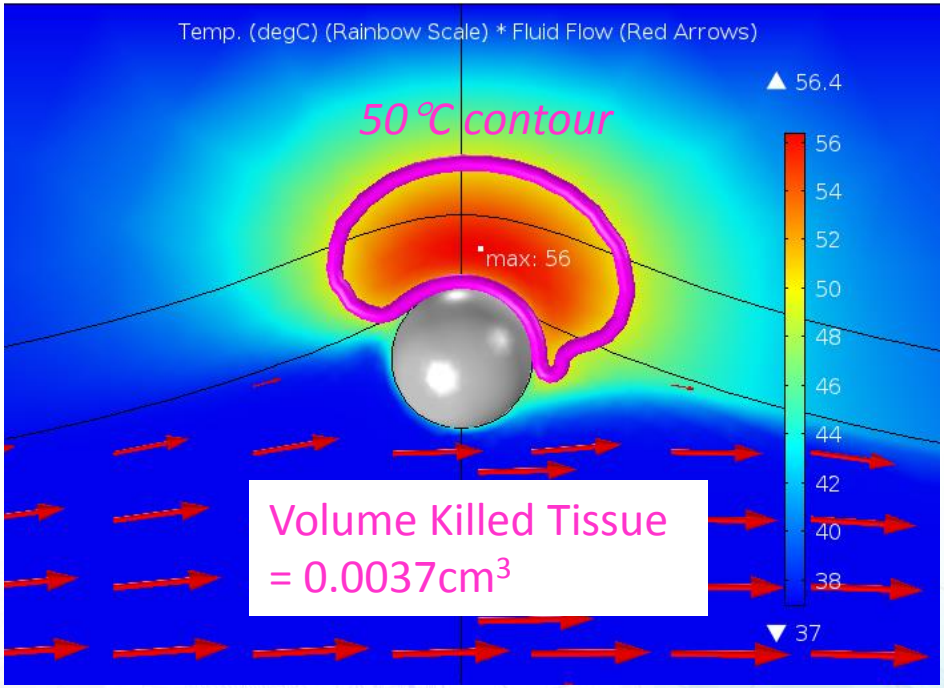
No bio heat Equation

$$\rho C_p \frac{\partial T}{\partial t} - \nabla \cdot k\nabla T = \tfrac{1}{2}\Re(\mathbf{J}^* \cdot \mathbf{E})$$

Add bio heat equation to bulk (Perfusion)

$$\rho C_p \frac{\partial T}{\partial t} - \nabla \cdot k\nabla T = \tfrac{1}{2}\Re(\mathbf{J}^* \cdot \mathbf{E}) + \rho_b C_{p,b} \omega_b (T_b - T)$$





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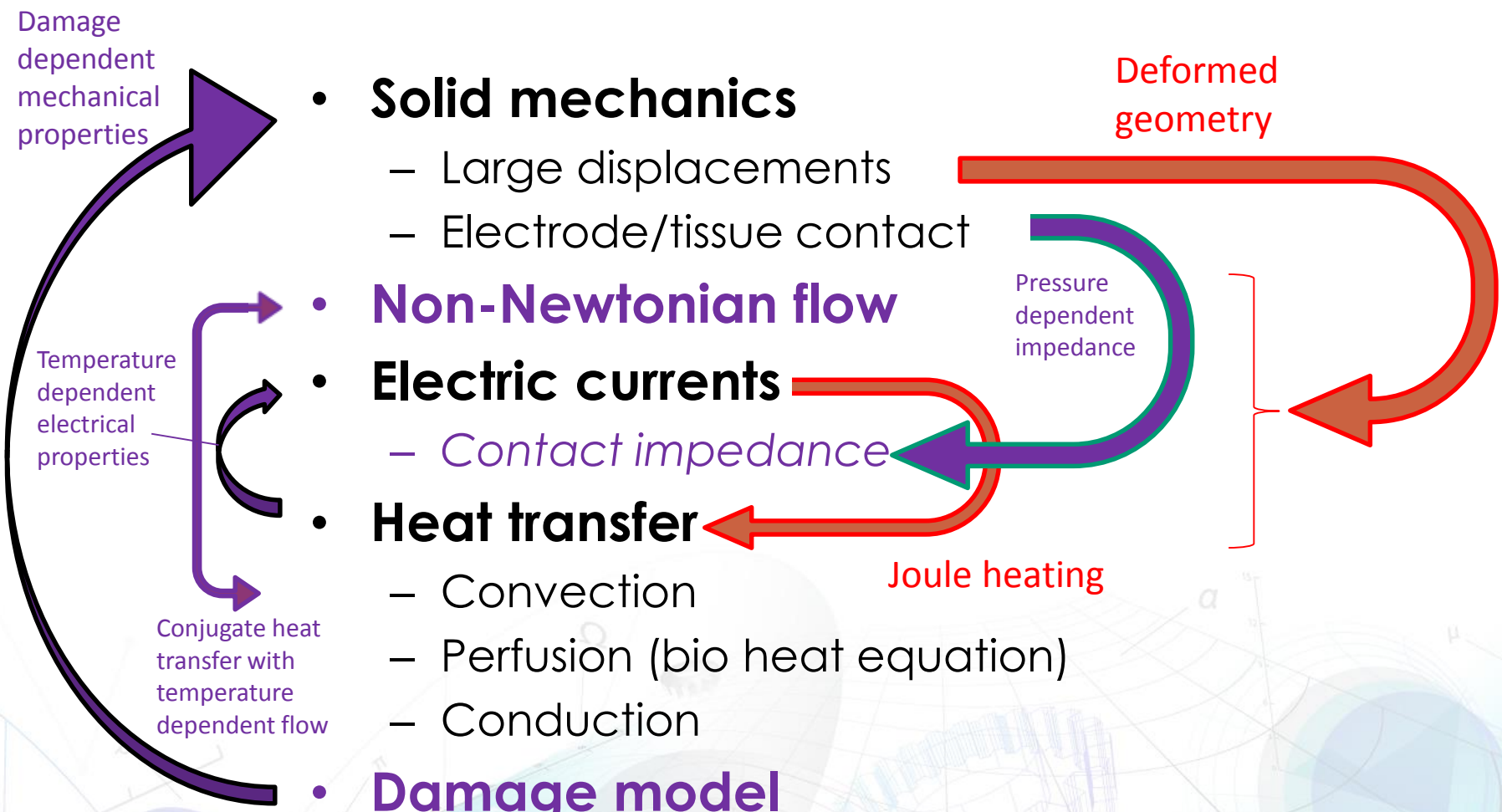
Summary

- RF tissue ablation model/methodology
- Critical factors identified
  - tissue deformation and blood flow critical
  - perfusion has a relatively small effect on killed tissue zone size

Further implementation



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