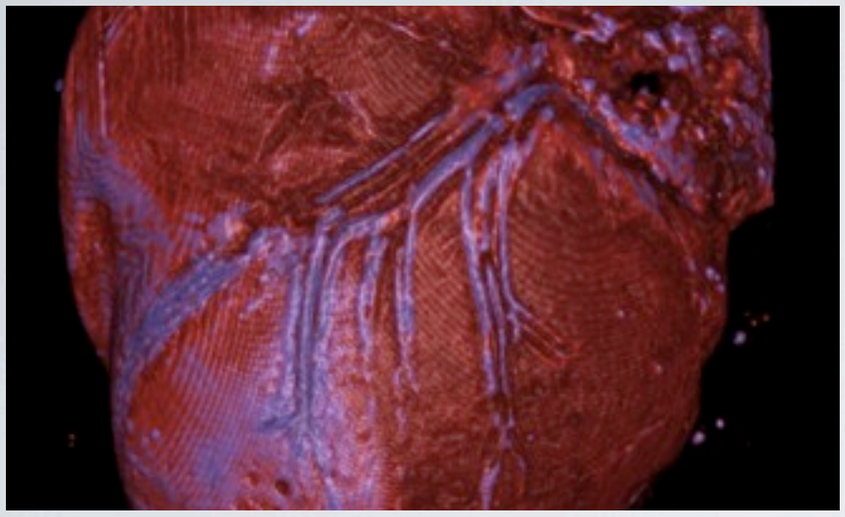
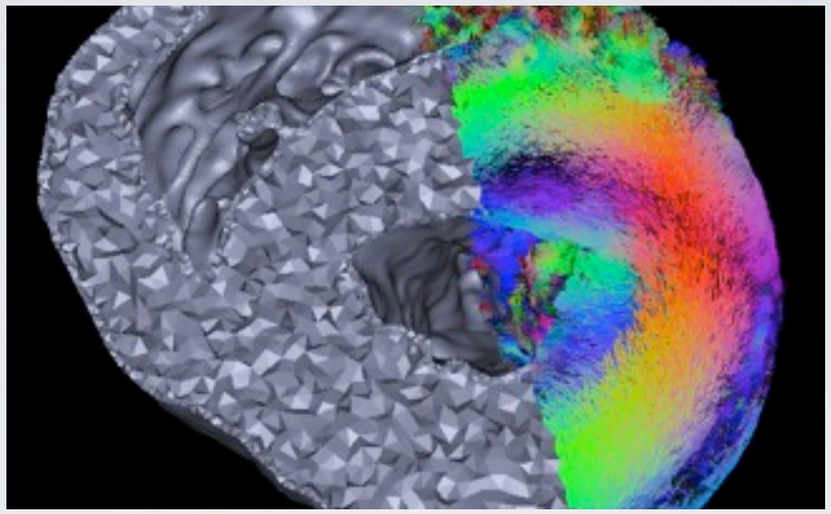
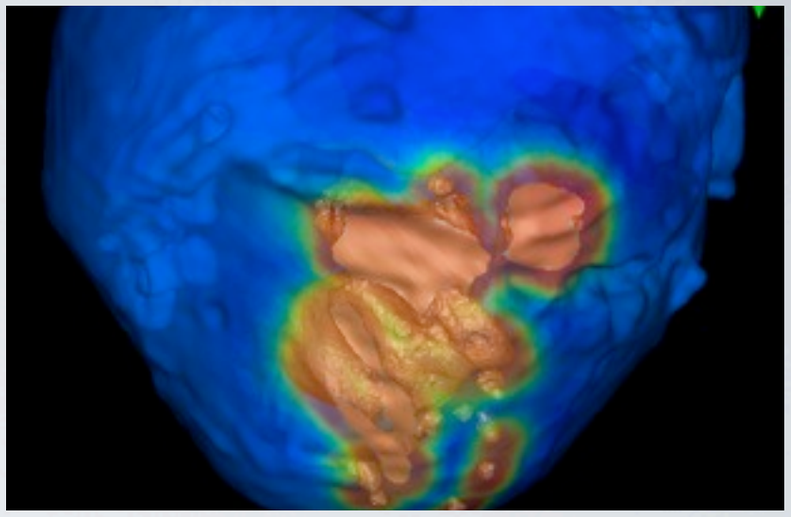




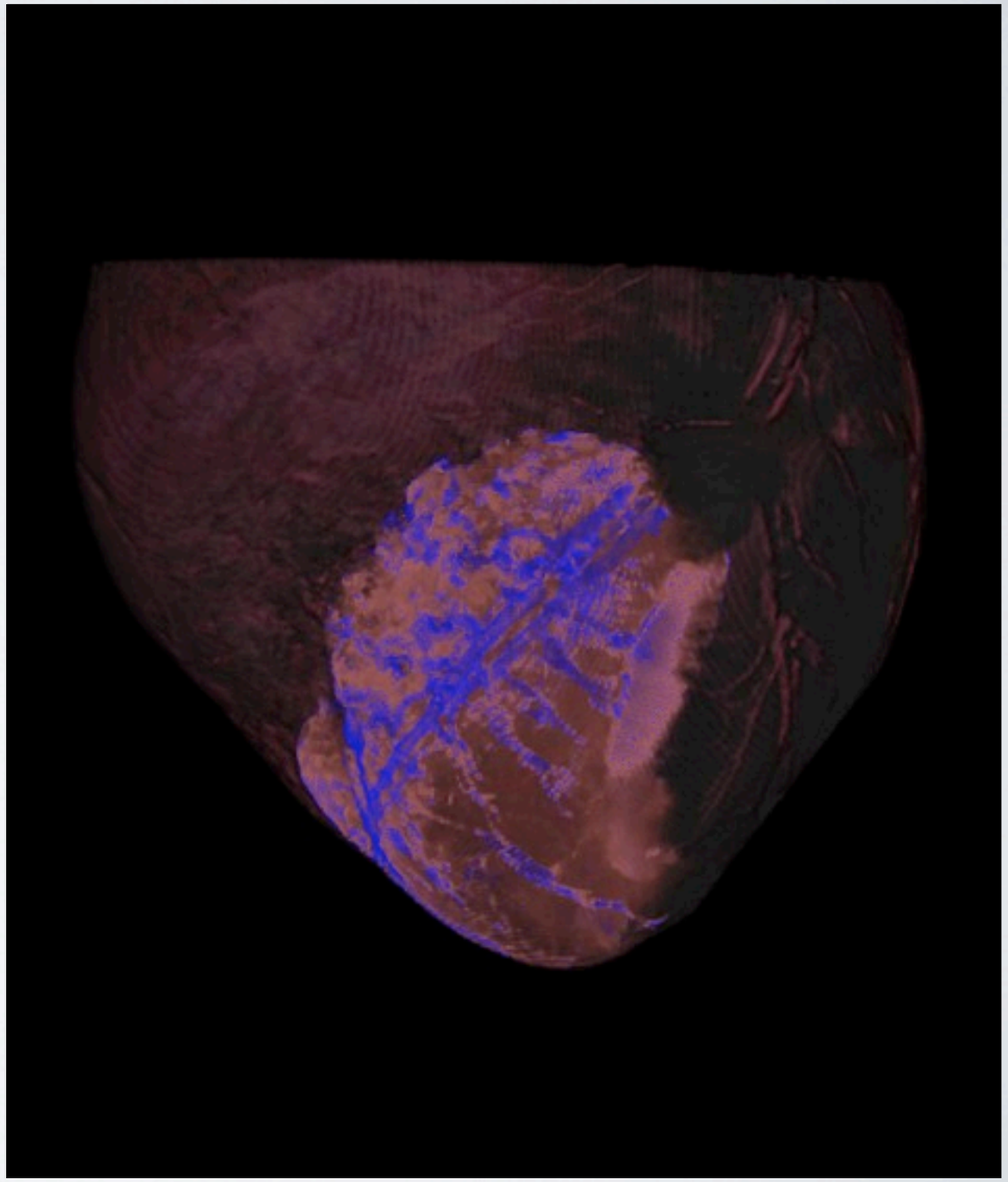
WORLD CONGRESS 2009

Evaluating the Effects of Border Zone Approximations with Subject Specific Ischemia Models

D.J. Swenson, J.G. Stinstra, B.M. Burton, K.K. Aras, L.J. Healy, and R.S. MacLeod
University of Utah

ISCHEMIA

- Ischemia is the lack of blood flow (oxygen)
- Action potentials reduce in amplitude
- Border zone injury current
- Projects to body surface, ECG
- ST segment elevation and depression indicates ischemia



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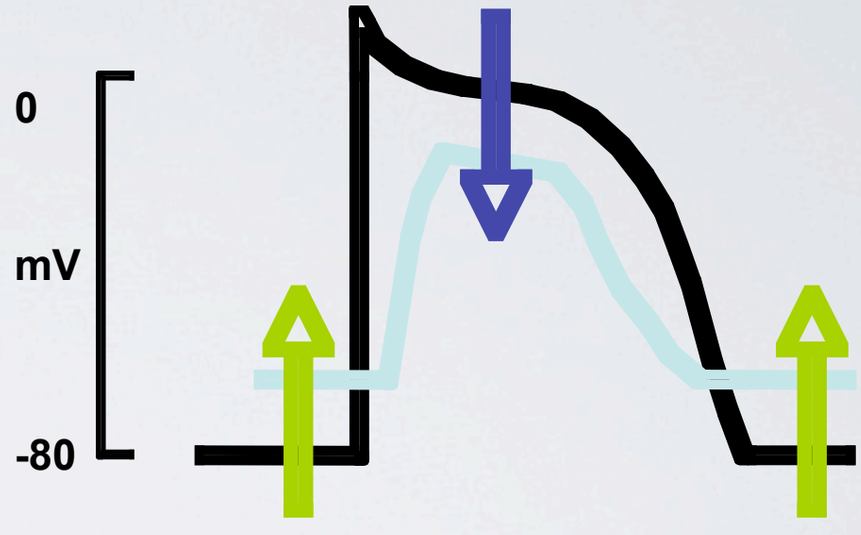

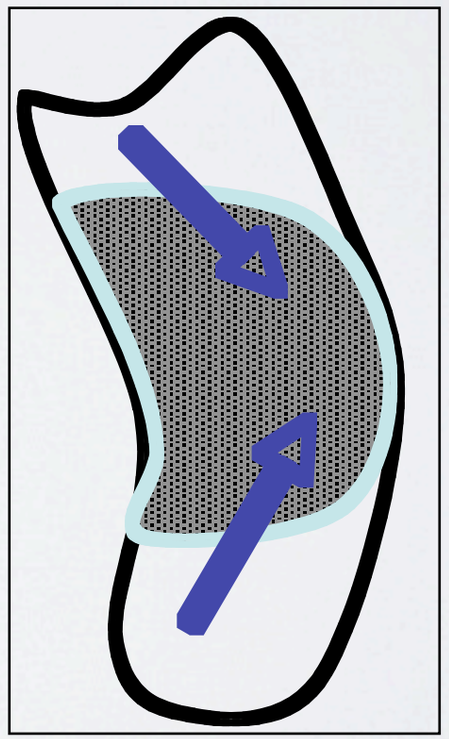

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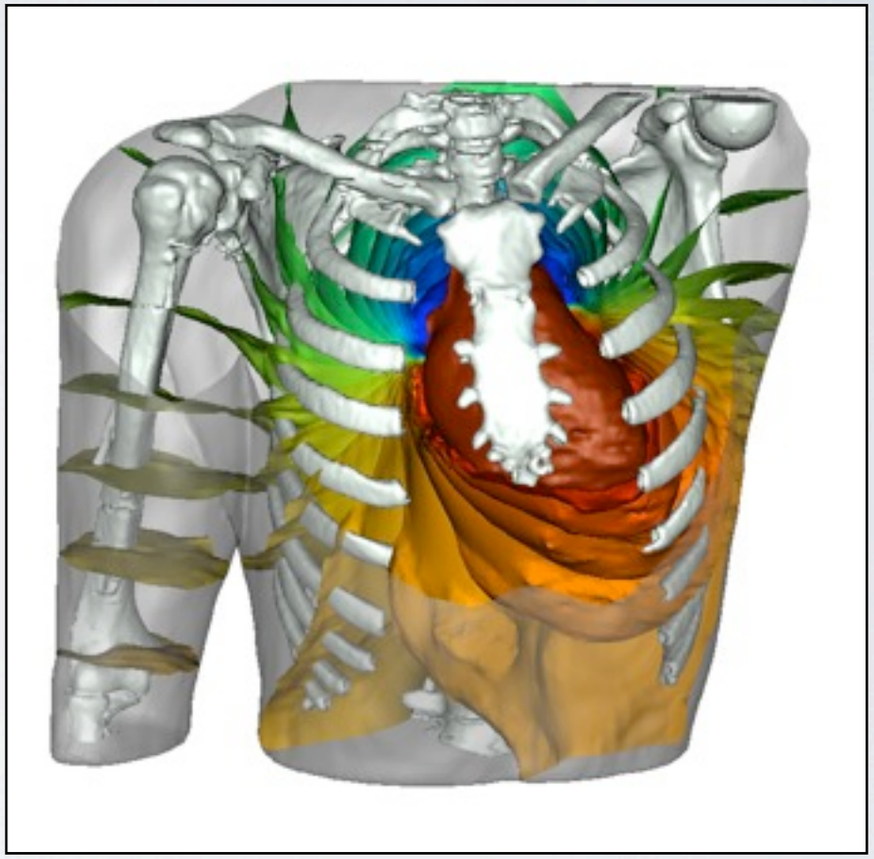
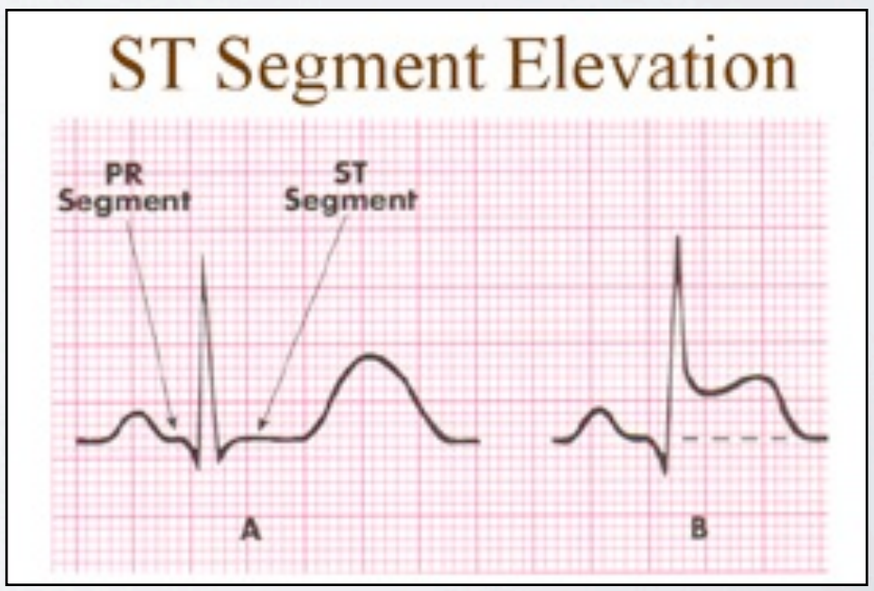
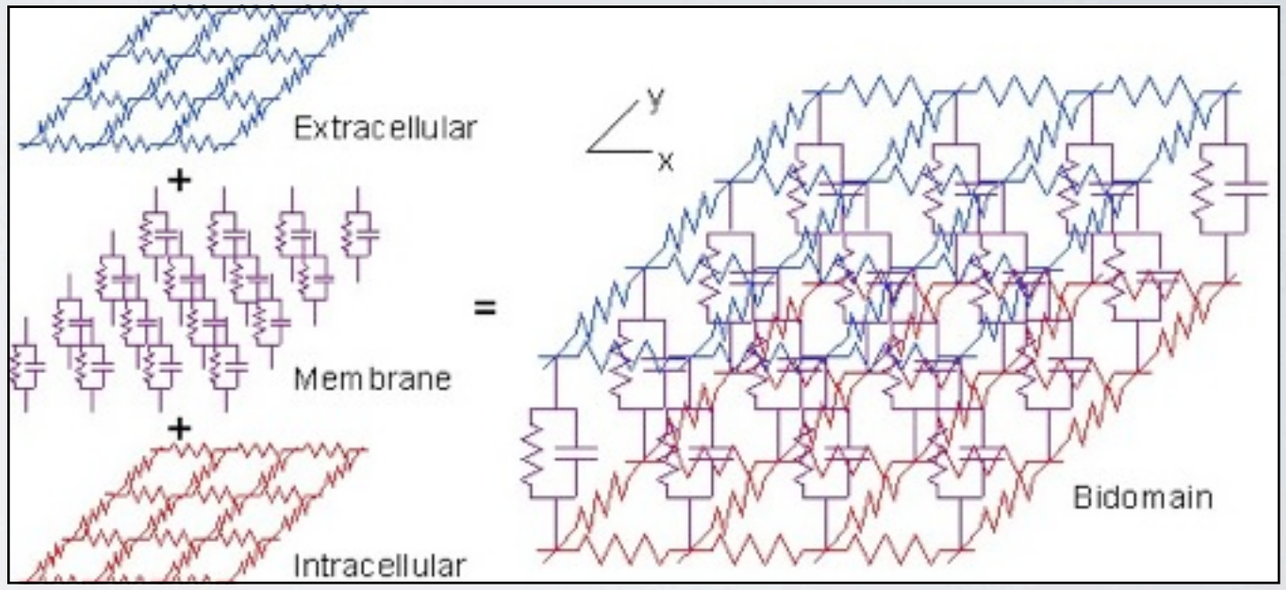
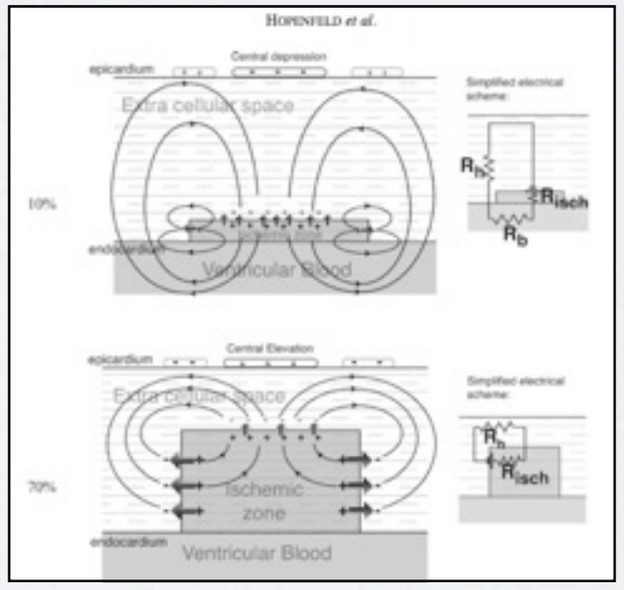


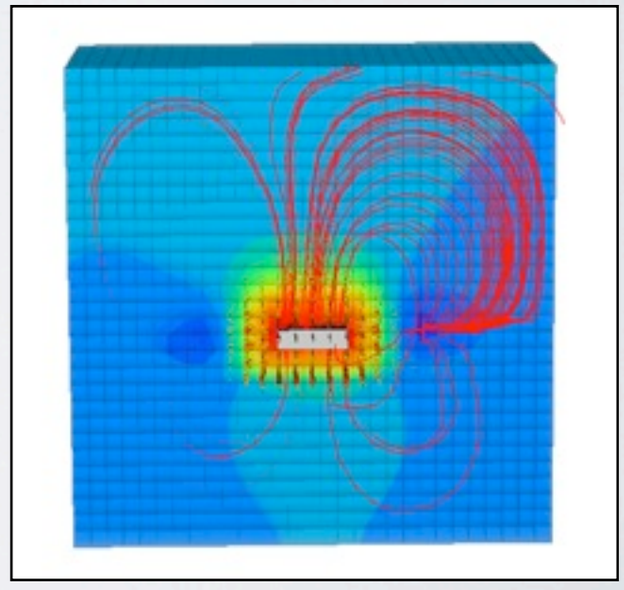


MODELING ISCHEMIA

- Bidomain equations model ischemia
- Computational models validate current loops and potential distributions
- Poor correlation to clinical data
- More geometric accuracy



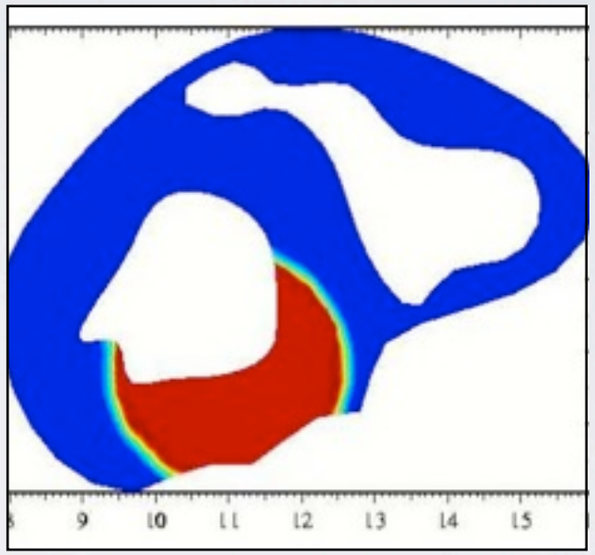




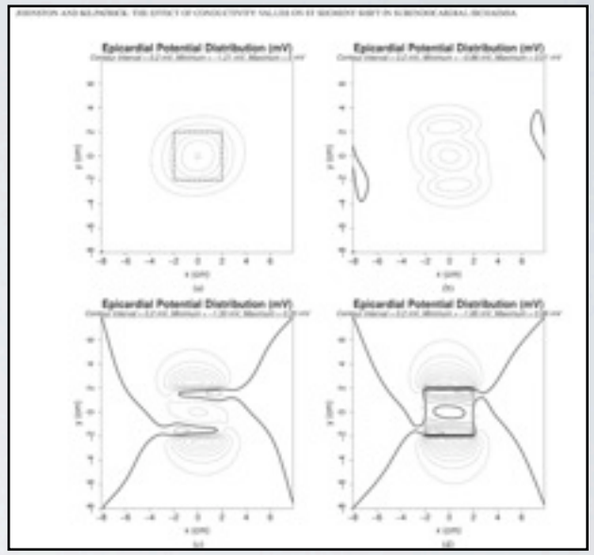
BORDER ZONE

- Three regions: healthy myocardium, ischemic myocardium and border zone
- Border zone 3 mm or less
- Geometric primitives used as ischemic zones

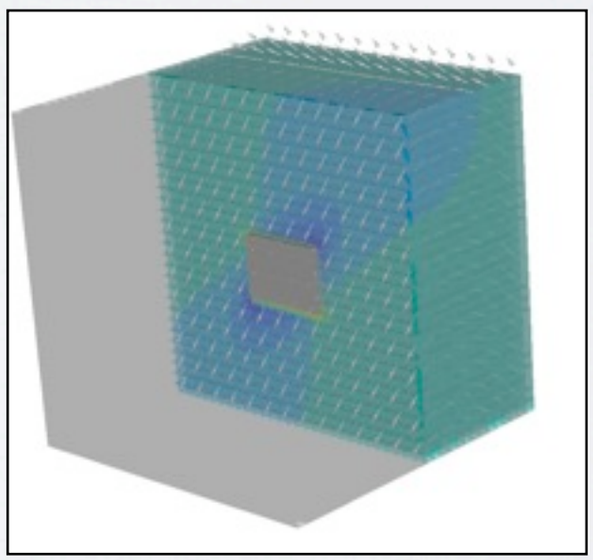
Kalkulo



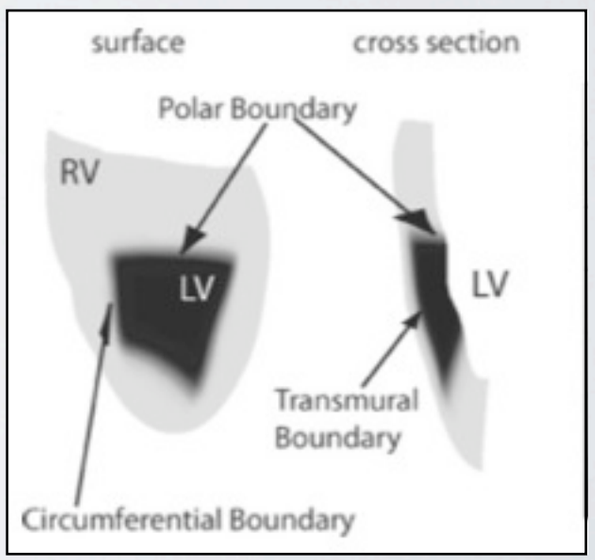
Kilpatrick



Generic

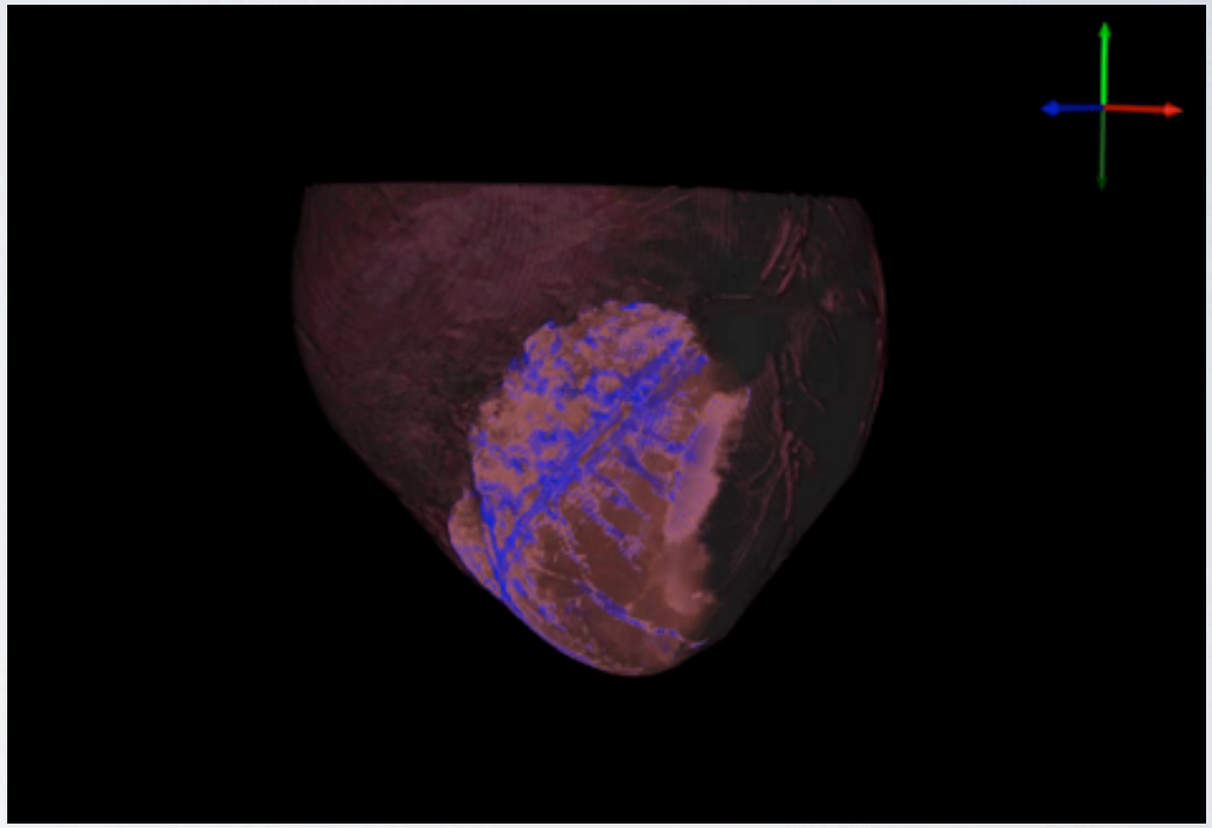


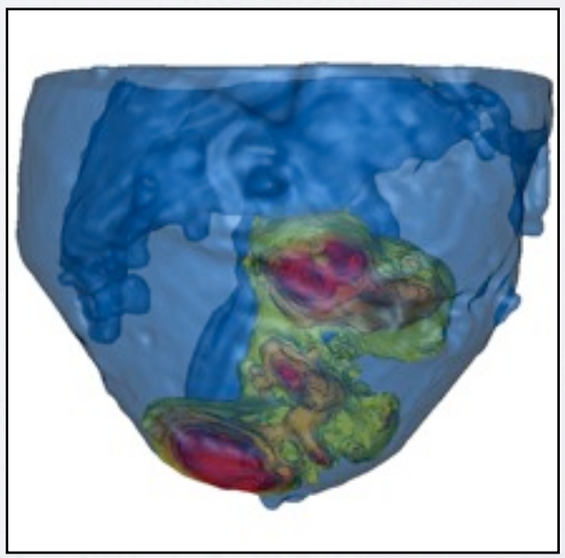
Hopenfeld

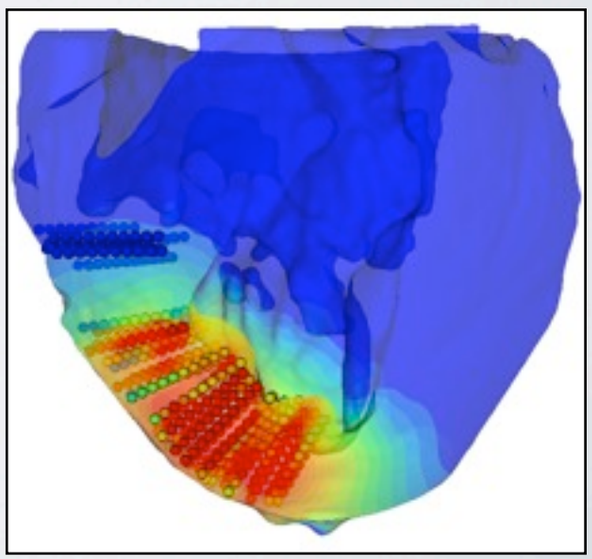


BORDER ZONE

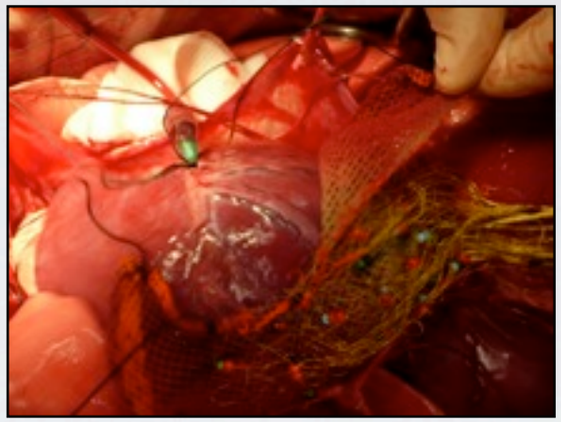
- Create more physiologically accurate border zones
- No distinct boundary in needle data
- Sharp border between two homogeneous regions derived from infarct data
- Critical region in for injury currents

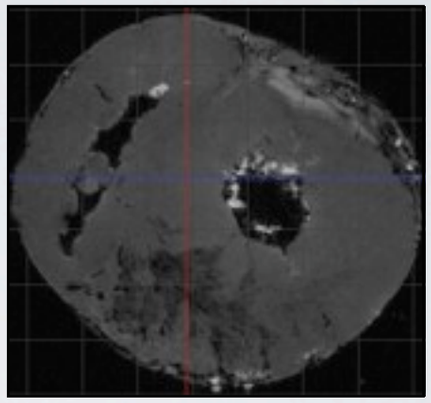


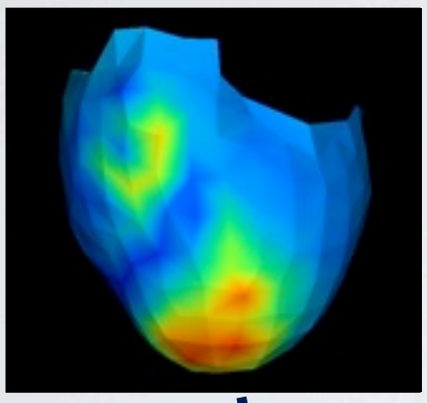




SUBJECT SPECIFIC MODEL

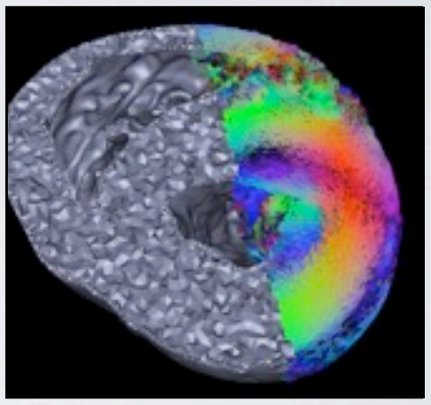


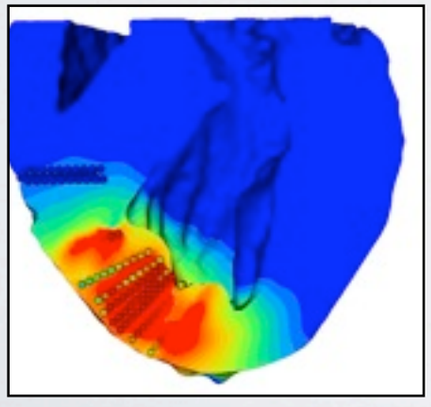




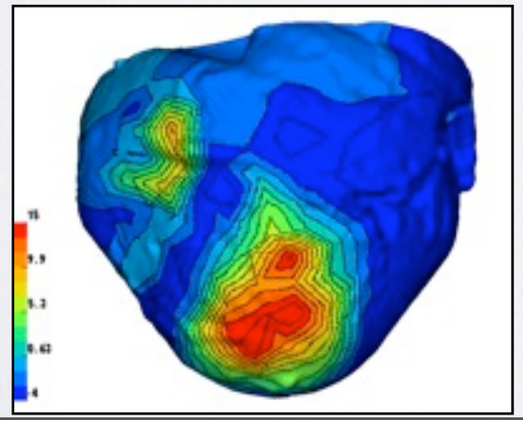
Experimental Data

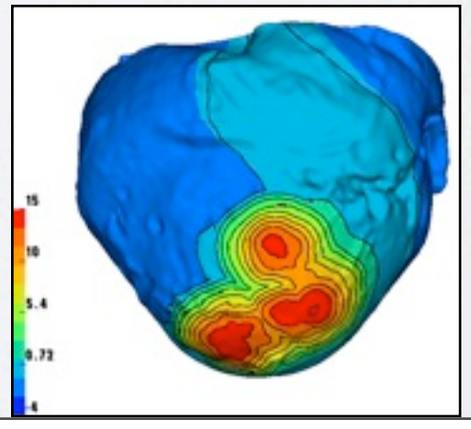
Subject Specific Model

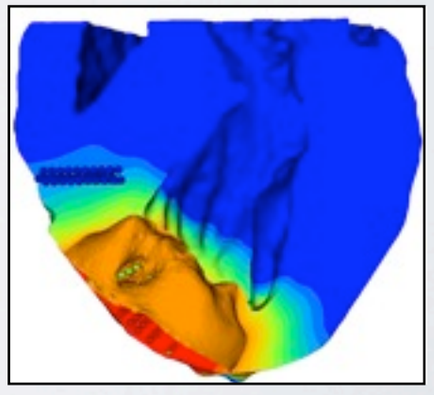




Compare Measured Data to Simulated Data

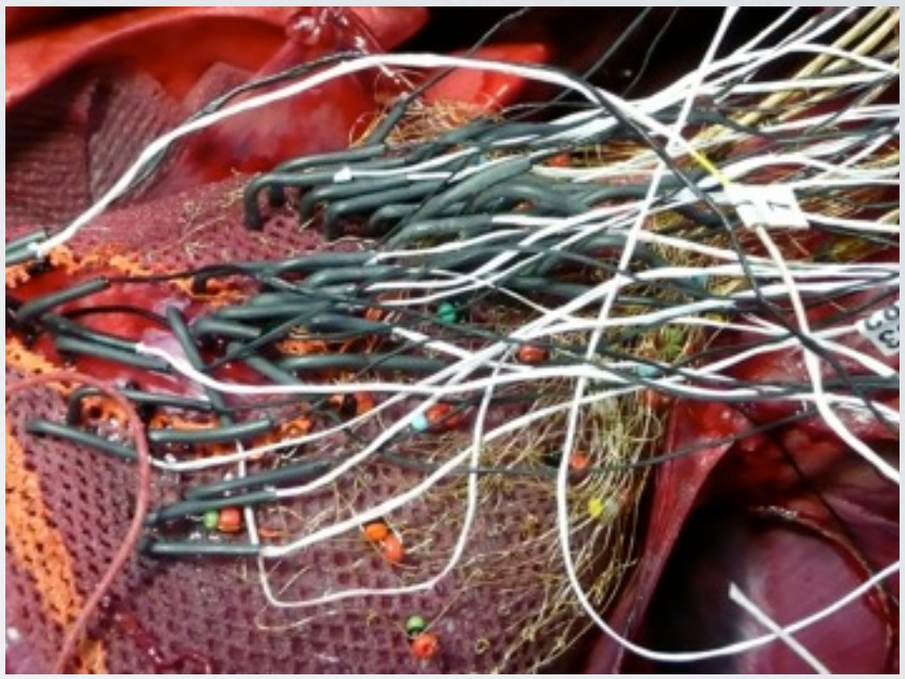


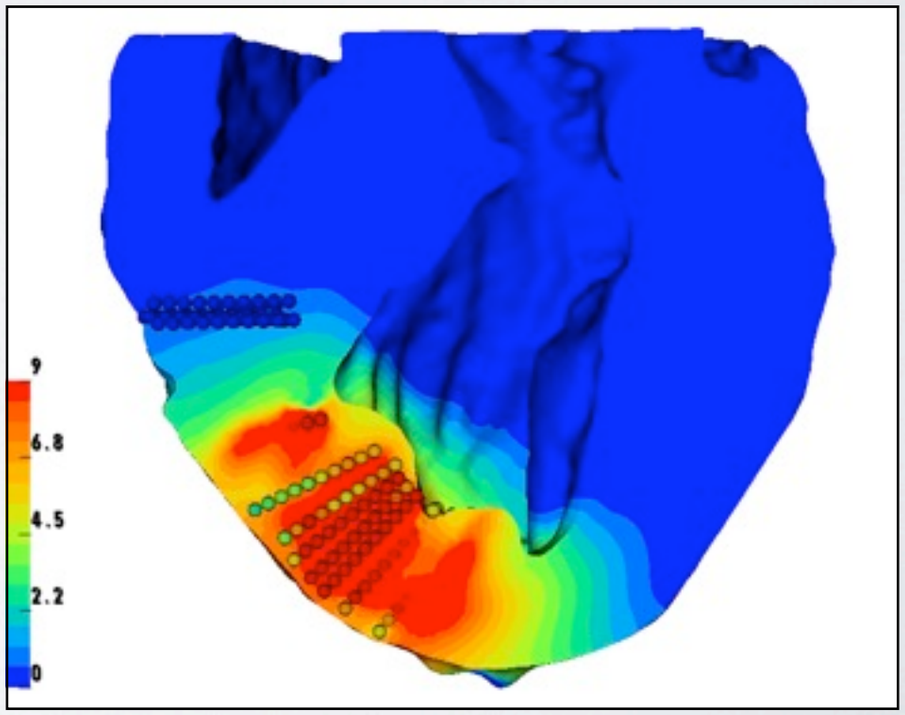




EXPERIMENTAL DATA

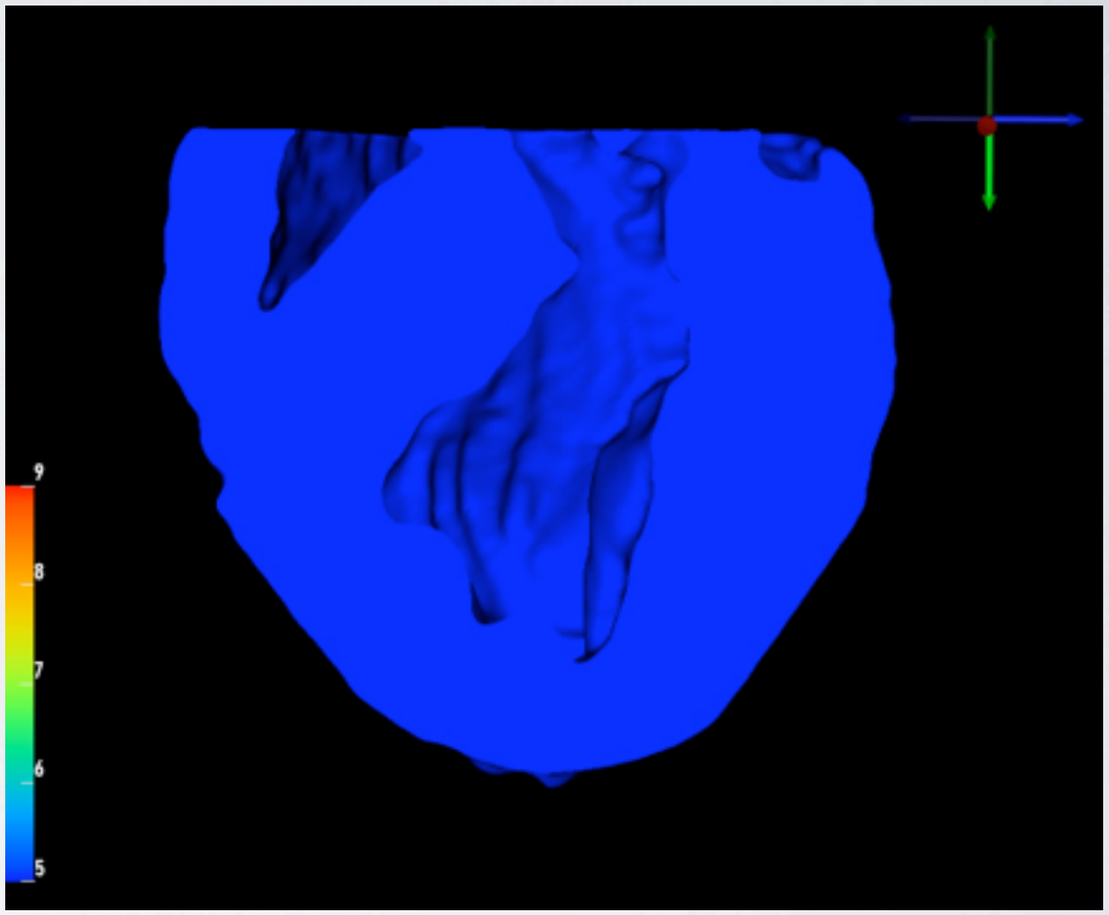
- Ischemia induced in canine LAD
- 247 electrode sock and 450 plunge needle electrodes used to record data
- Registered to landmarks on the heart for alignment with the MRI
- Linear and volumetric Laplacian interpolation for the sock and needle data

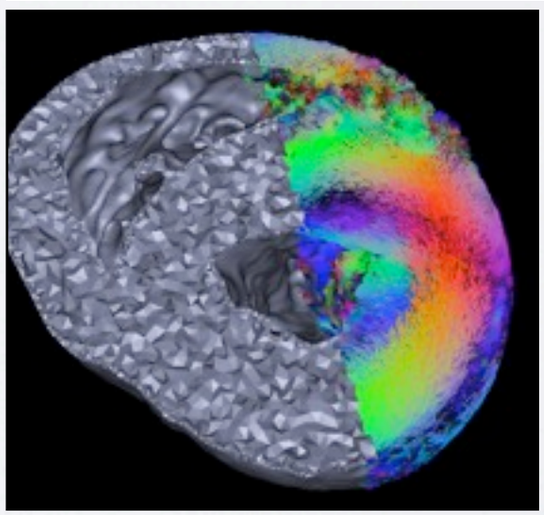


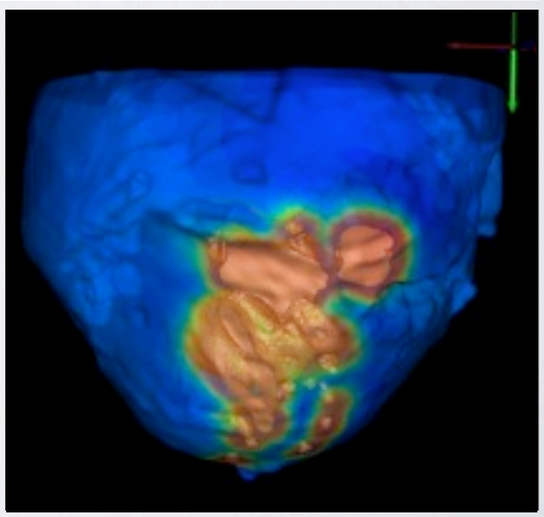


MODEL CREATION

- MRI and DTI Scans
- Segmentation - Seg3D software.sci.utah.edu
- Marching cubes isosurfacing and Tetgen meshing - SCIRun
- Mapped fiber orientations to mesh - SCIRun
- Ischemic zone from needle







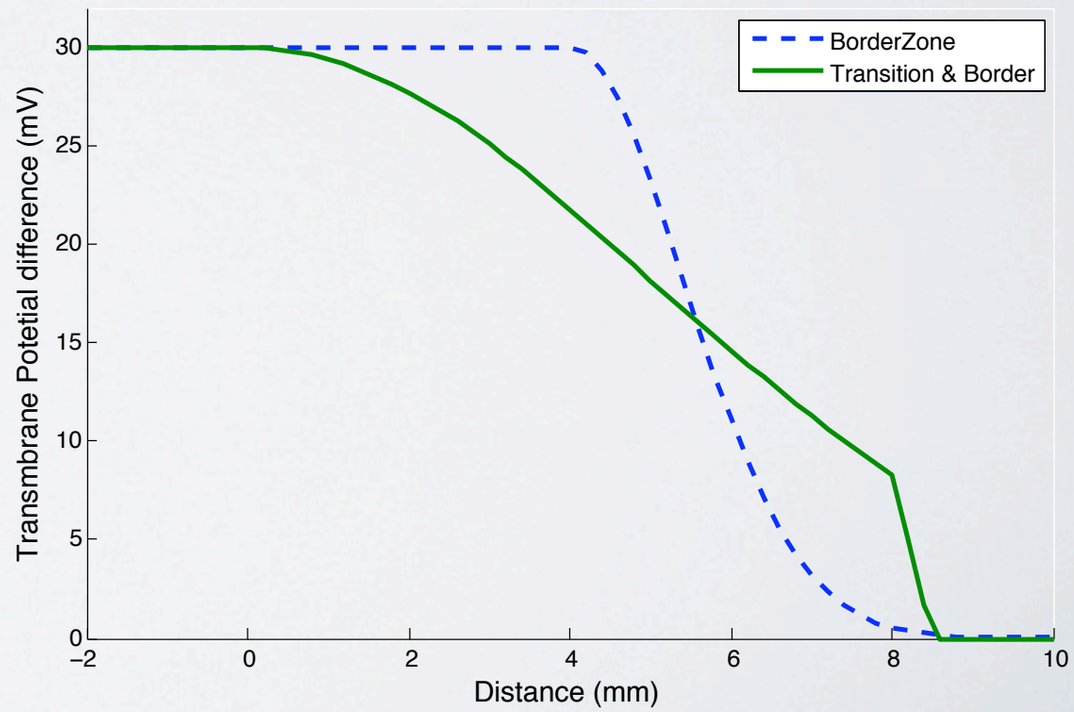
BORDER ZONE SIMULATION

- Bidomain equation we assume a transmembrane potential profile
- Conductivity from Stinstra et al
- Gaussian blurring of the edge for traditional distribution
- Explicitly modeled transition region for new distribution

$$\nabla \cdot (M_i + M_e)\nabla \phi_e = -\nabla \cdot M_i \nabla \phi_m$$

Table 1 Bidomain normalized conductivity values

	Healthy	Ischemic
Intracellular longitudinal conductivity	1	1
Intracellular transverse conductivity	.05	.05
Extracellular longitudinal conductivity	1	.5
Extracellular transverse conductivity	.333	.25



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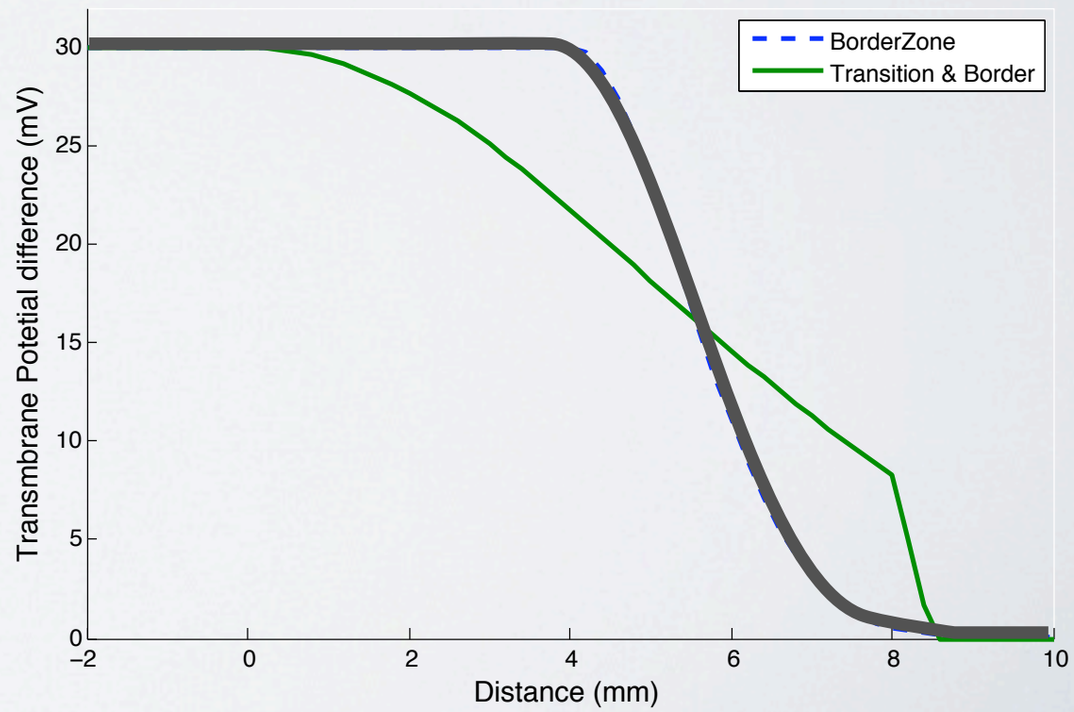

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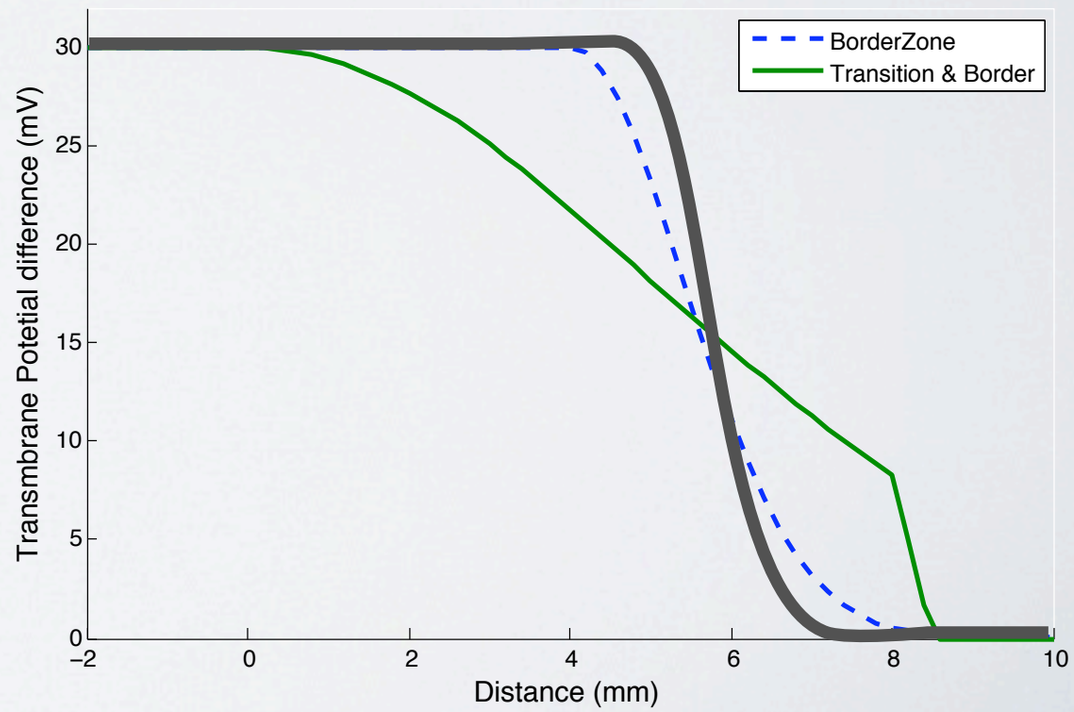

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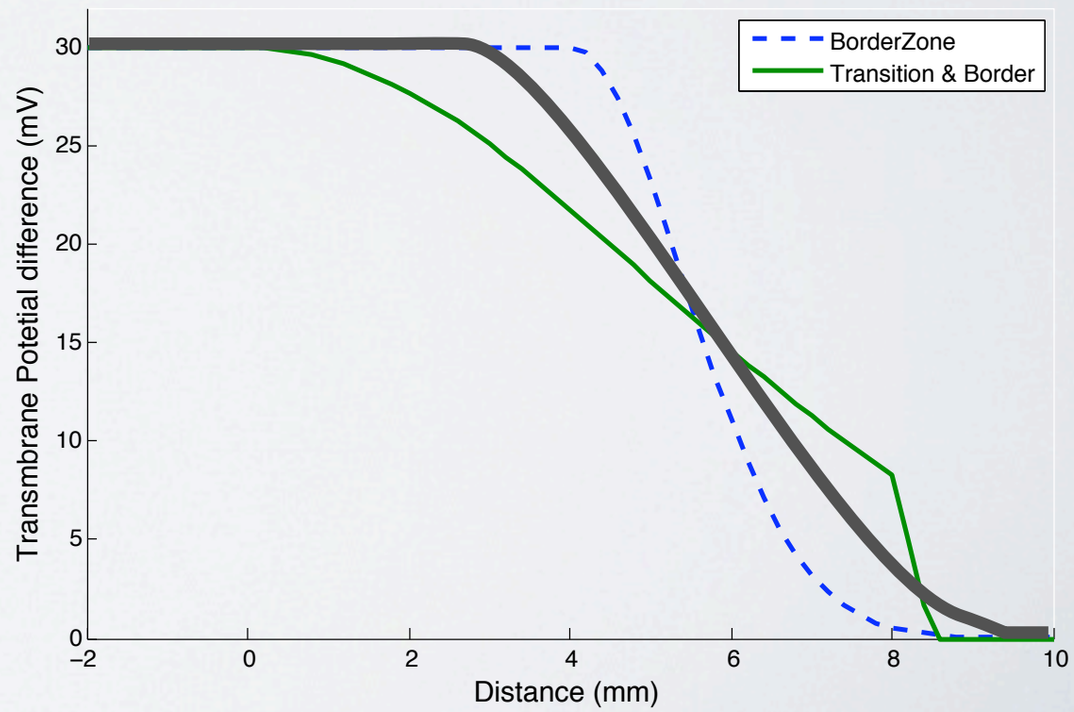

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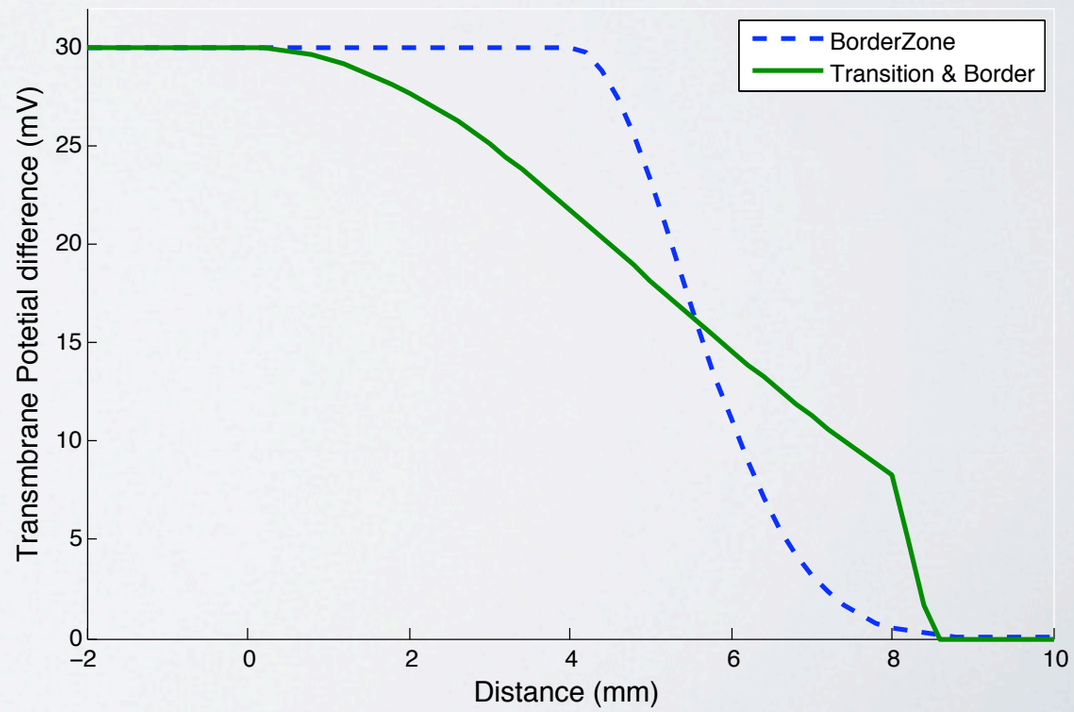
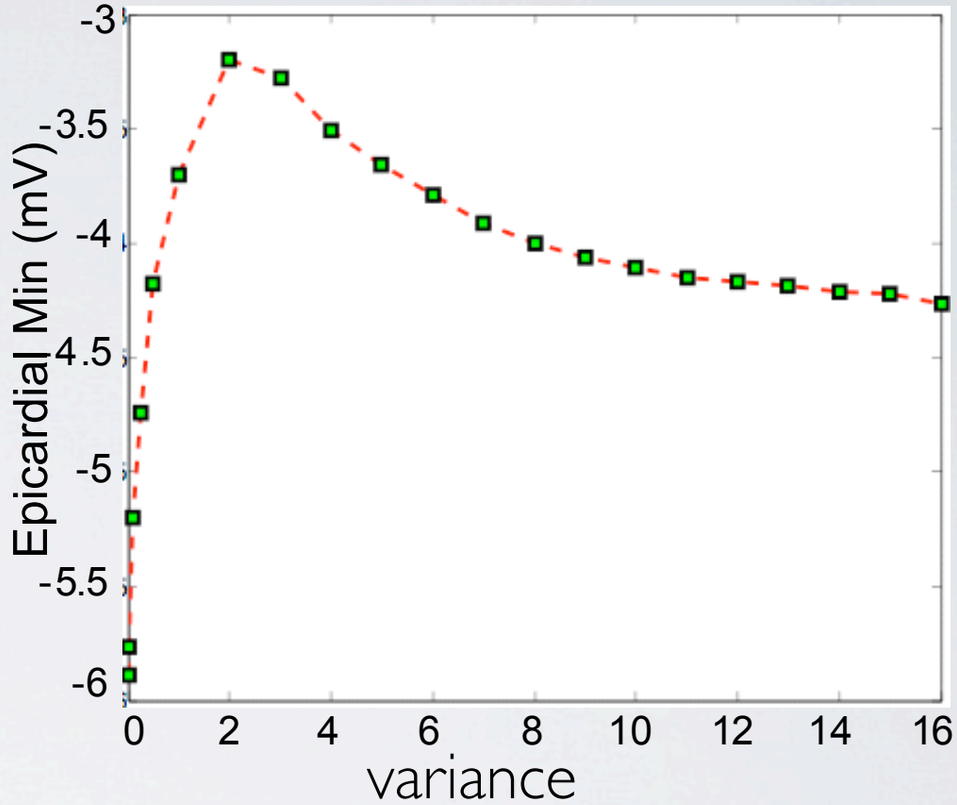
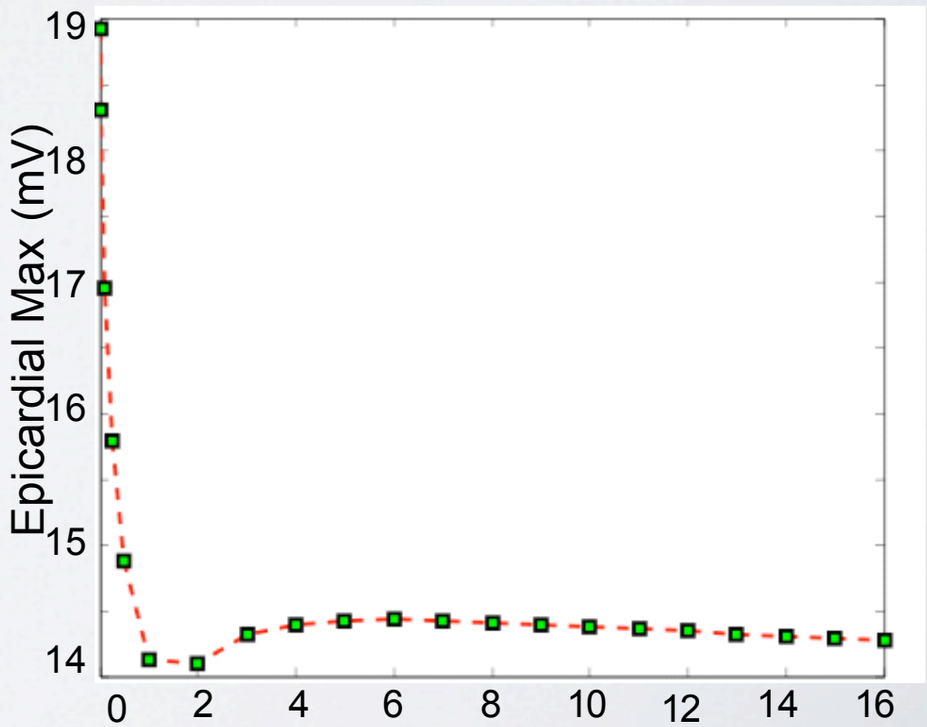


BORDER ZONE SENSITIVITY

- Adjusted the variance of the Gaussian distribution
- Highly sensitive for border zones less then a variance of 2 ~ 3mm
- Sharper transitions produced more localized depressions





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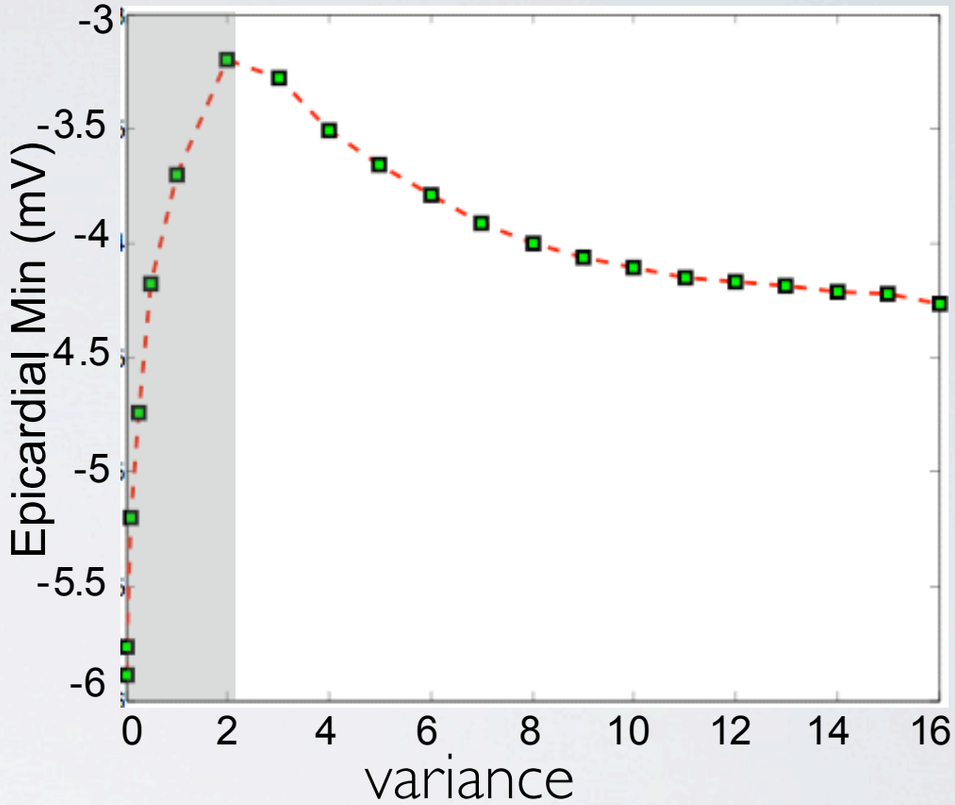

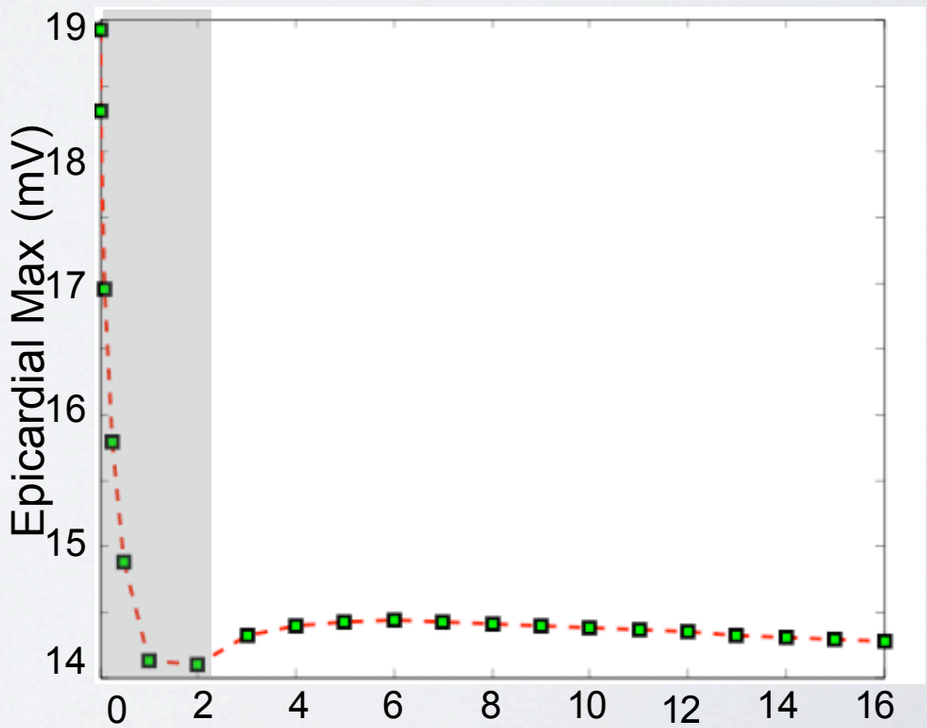

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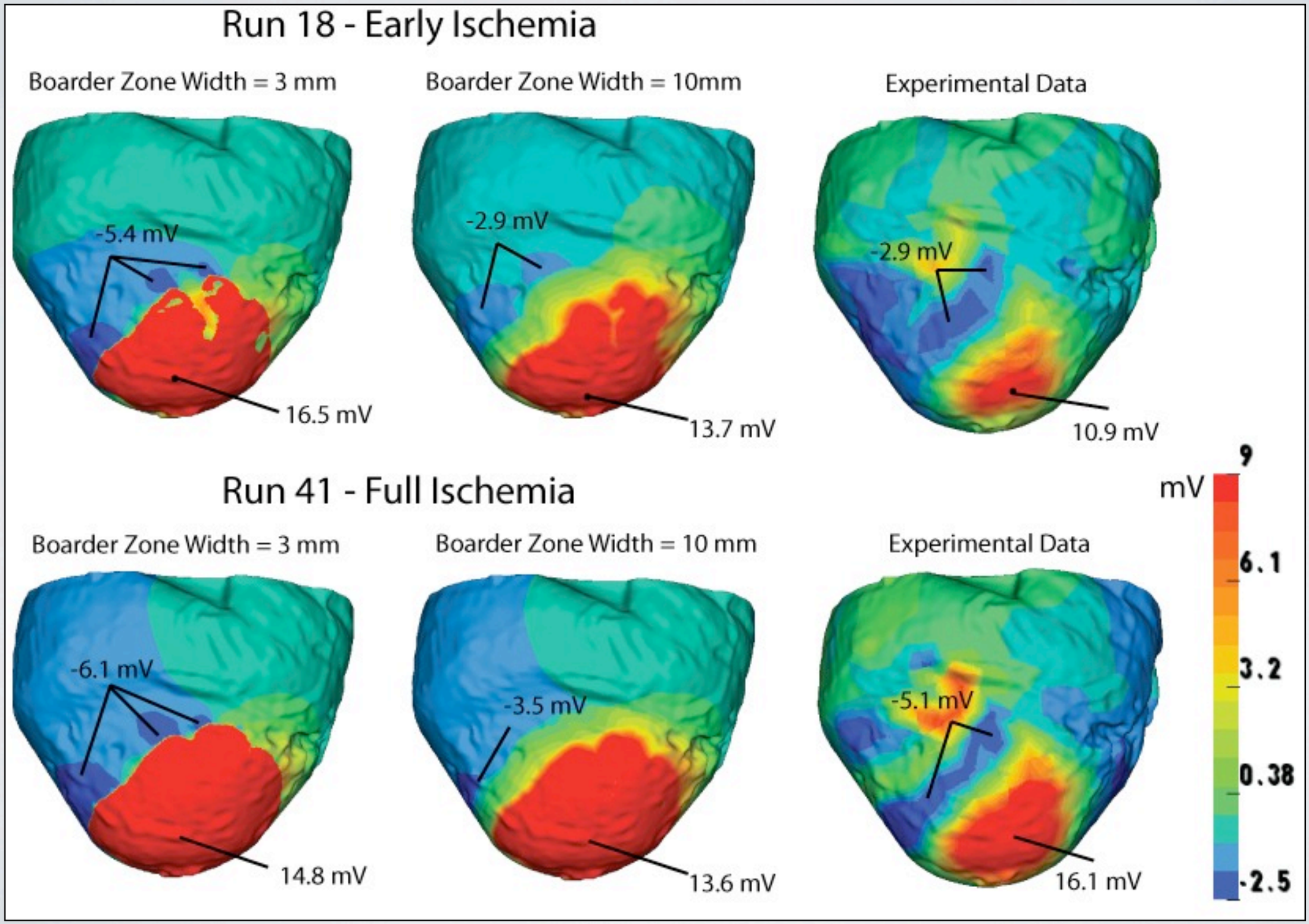
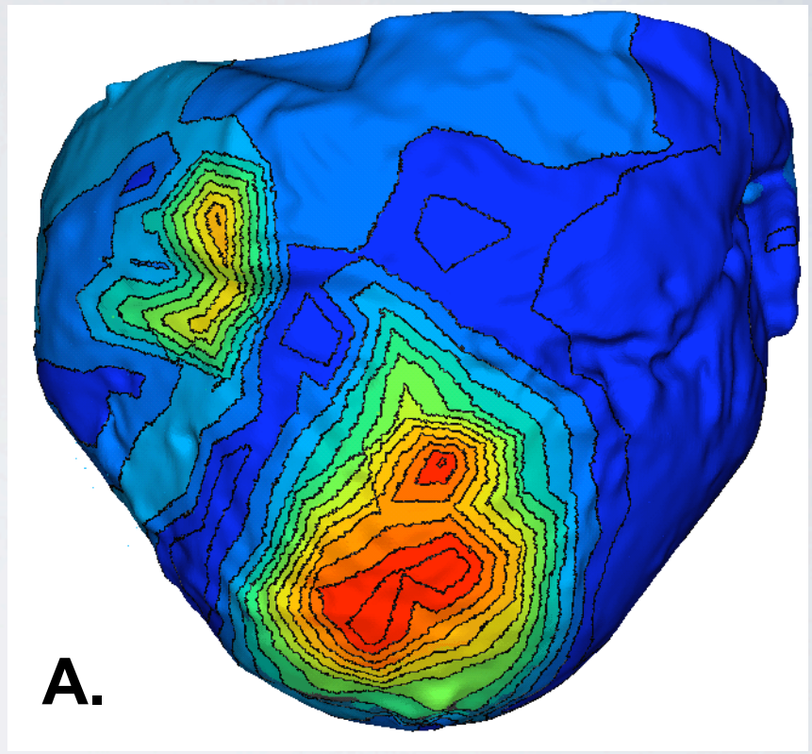


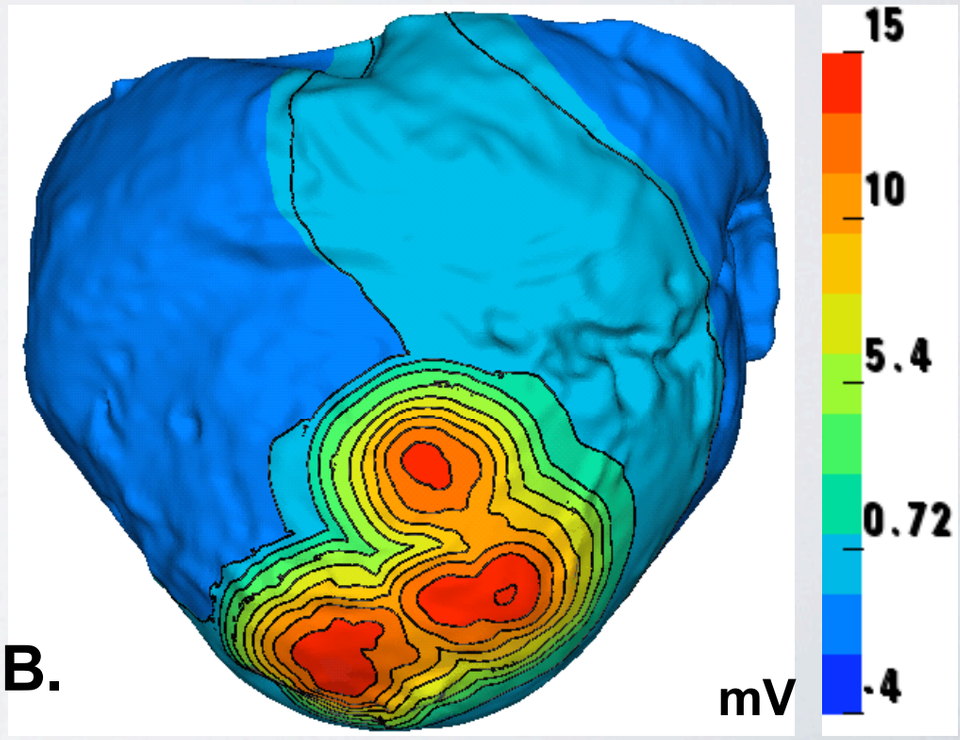
GRADIENT MAGNITUDE

- Unable to match the field gradients using the traditional model of a border zone
- Absence of a distinct ischemic border in the needle data
- The transition region created field gradient and magnitudes similar to those in the recorded data

Recorded



Simulated



CONCLUSIONS

- Border zone profile plays a significant role in the epicardial potentials distribution
- The border zone requires complex modeling
- Improved geometric representations of the border zone, adding a transition region, improves the simulation results

CURRENT WORK

- Use transmural needles to quantify border zone profile
- Extend model to multiple species, including the role of fiber structure
- Improve registration techniques

QUESTIONS

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Cardio Vascular Research and Training Institute
Scientific Computing and Imaging Institute