Wave Equation Based Interpolation

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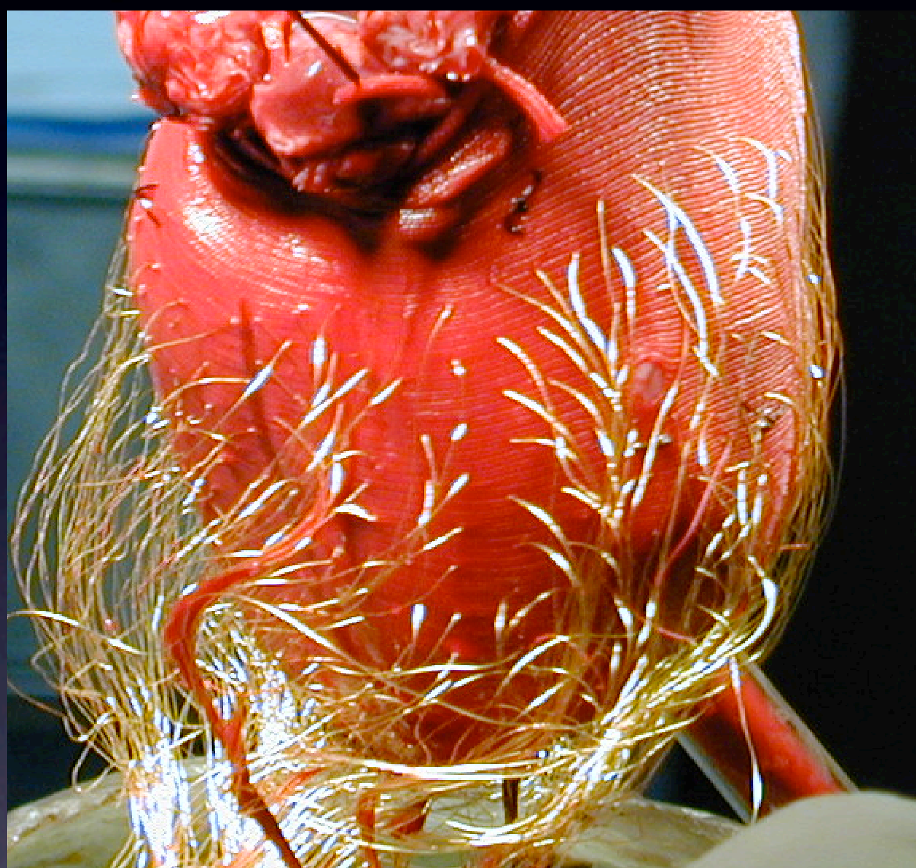
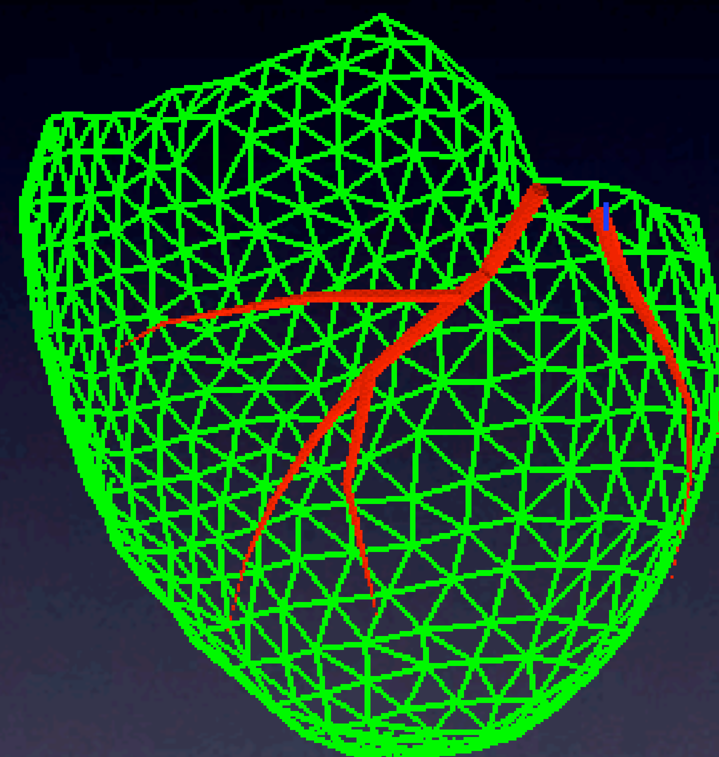
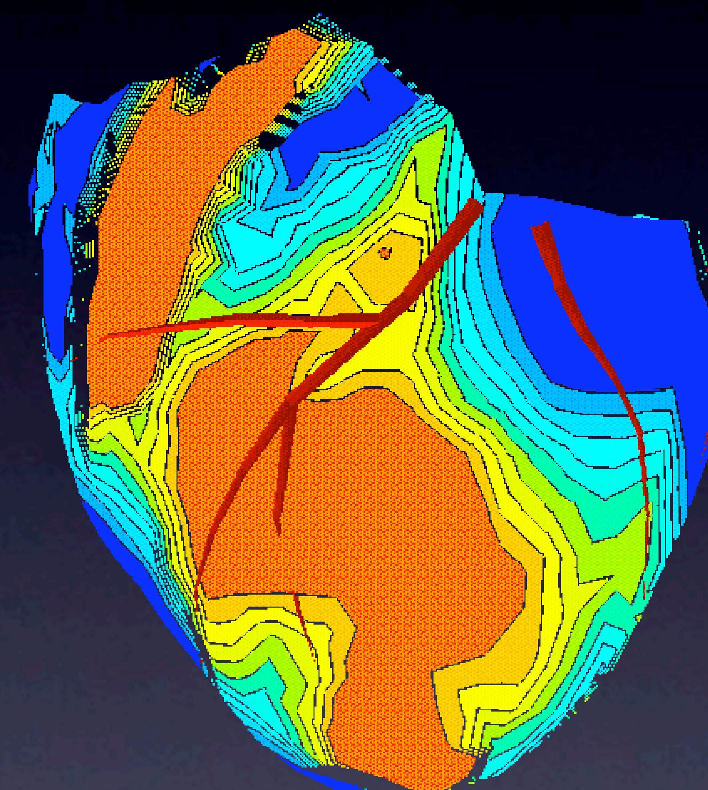
Cardiac Mapping



Discrete Electrical Measurements



Interpolation



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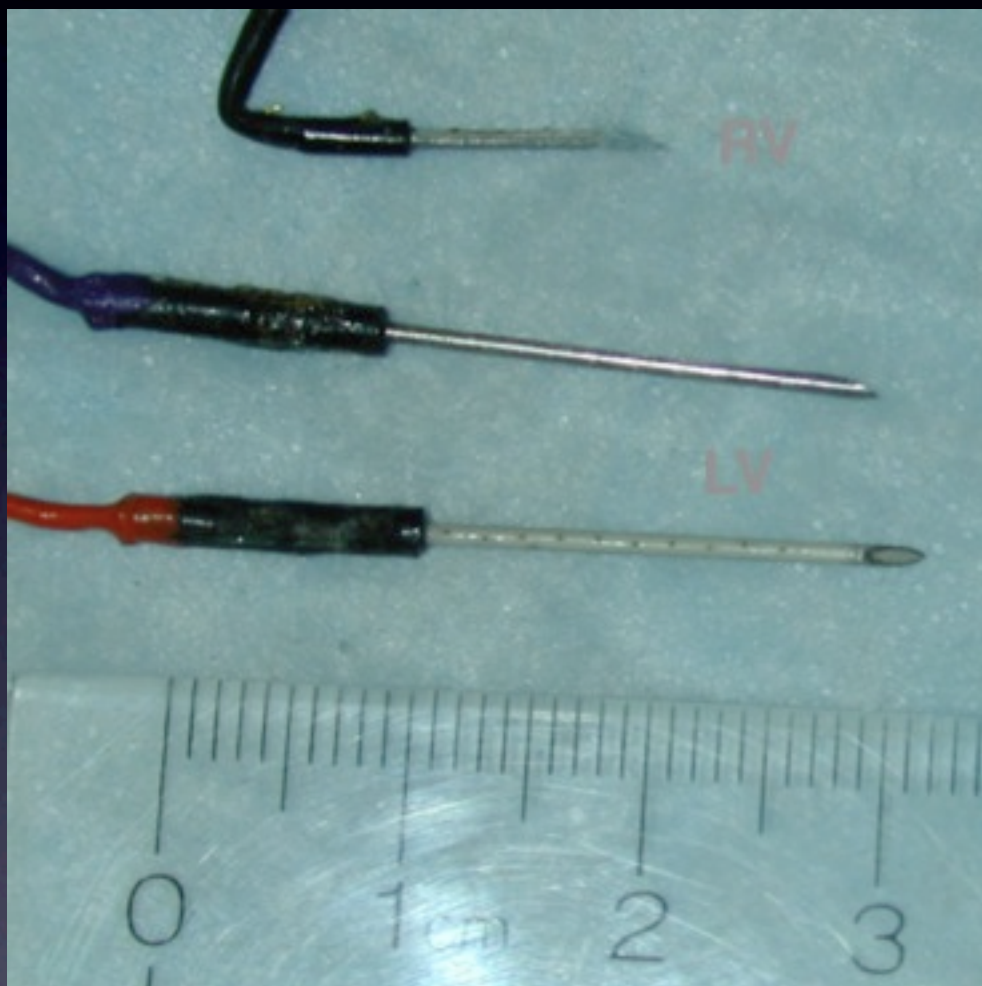
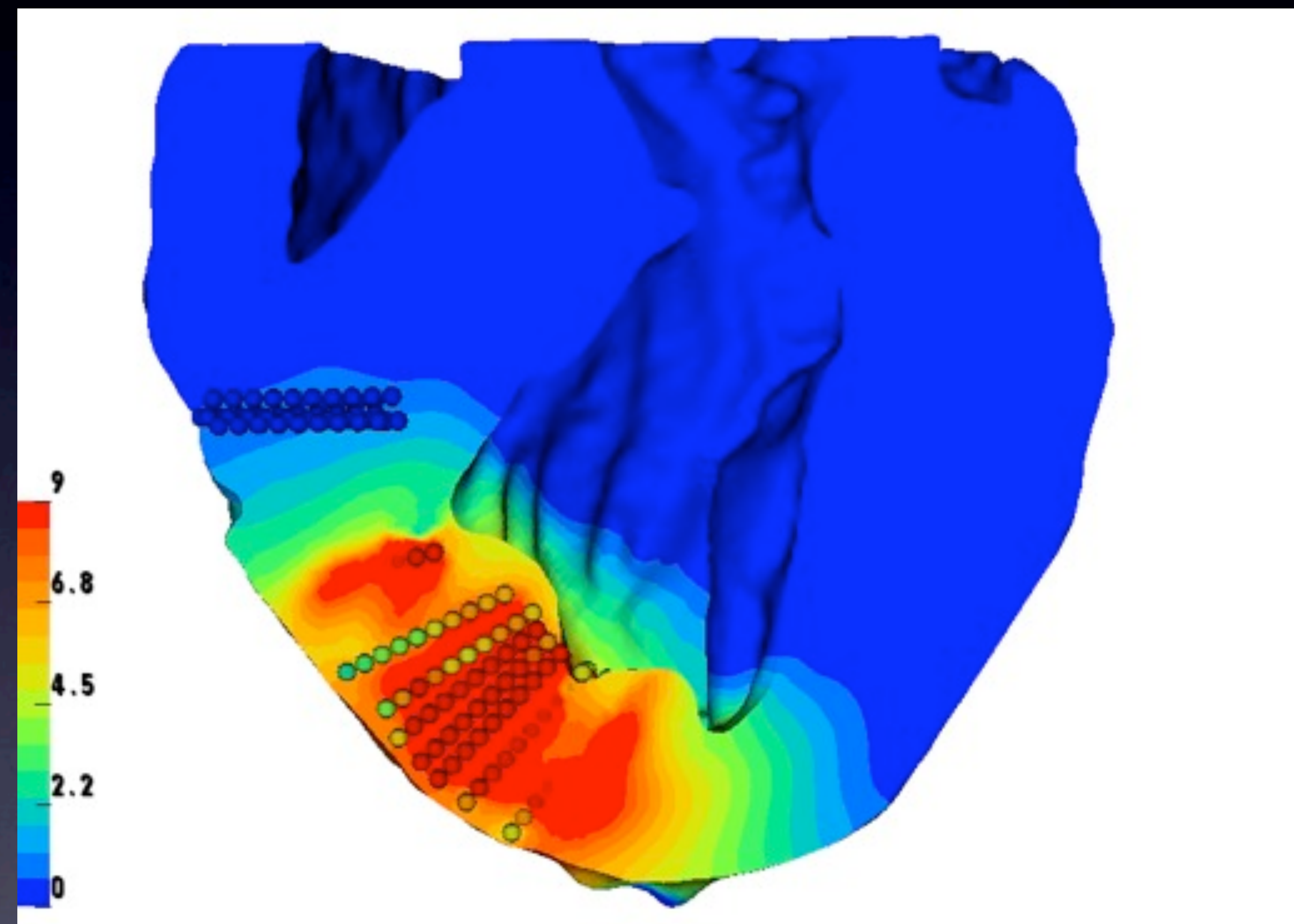
Cardiac Mapping



Needle Electrodes



Volumetric Interpolation

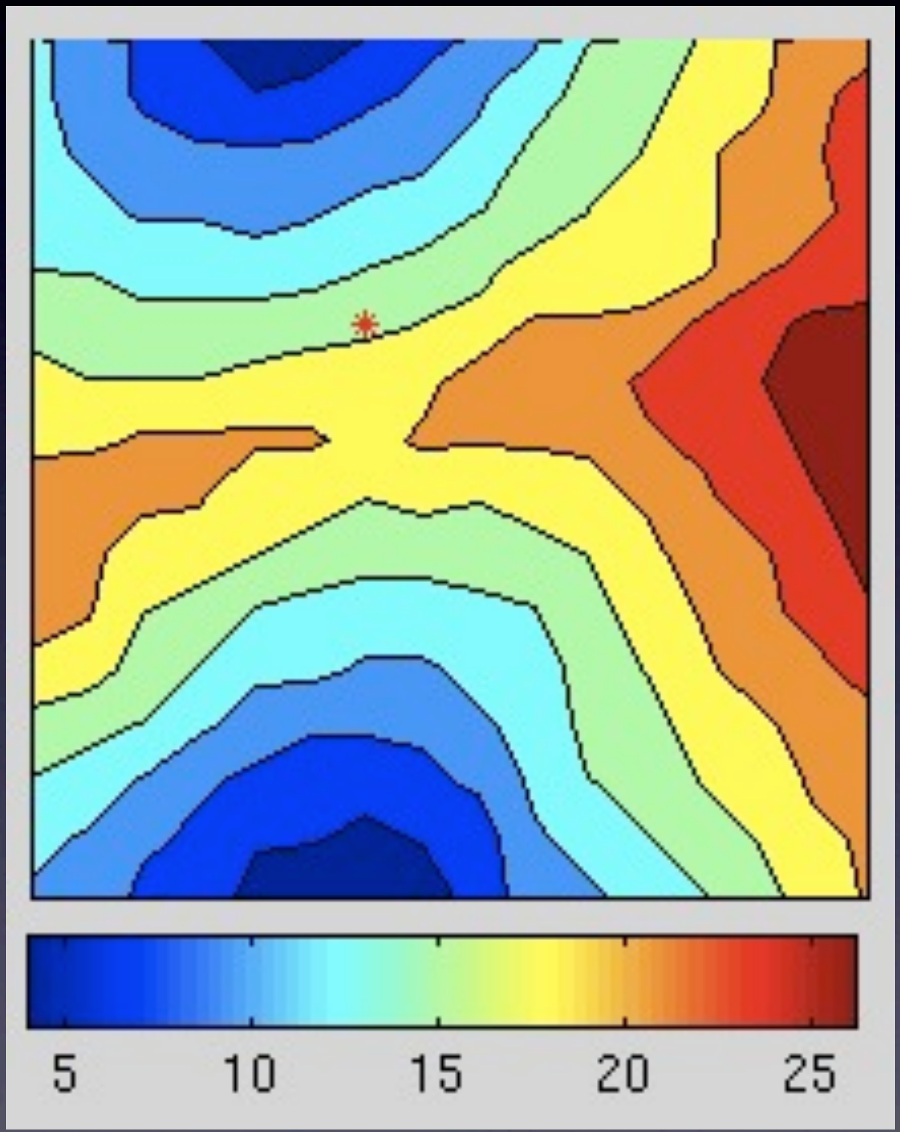
Potential Maps

Relative min and max

Activation times

Gradients

- Direction
- Border zones



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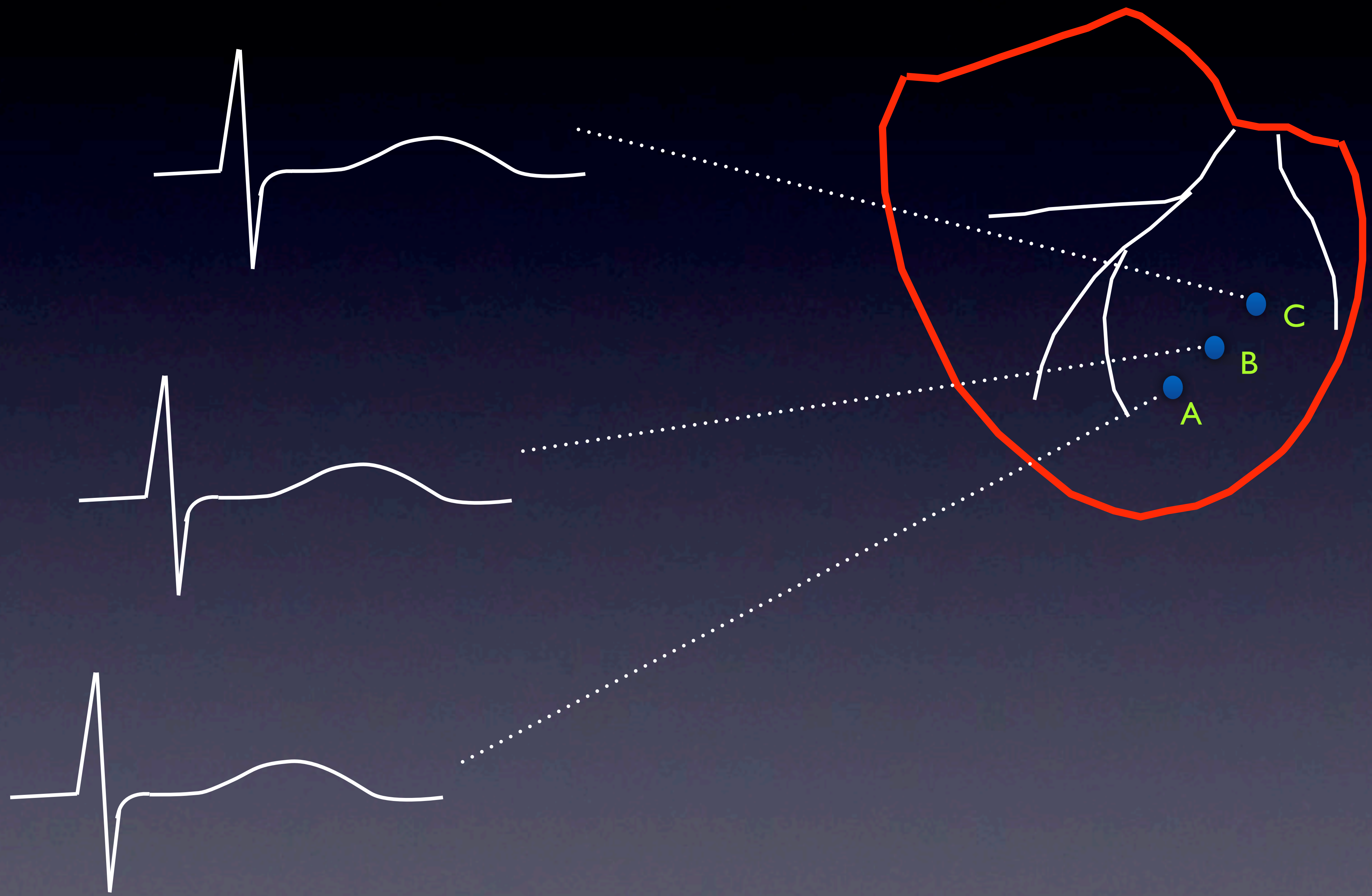

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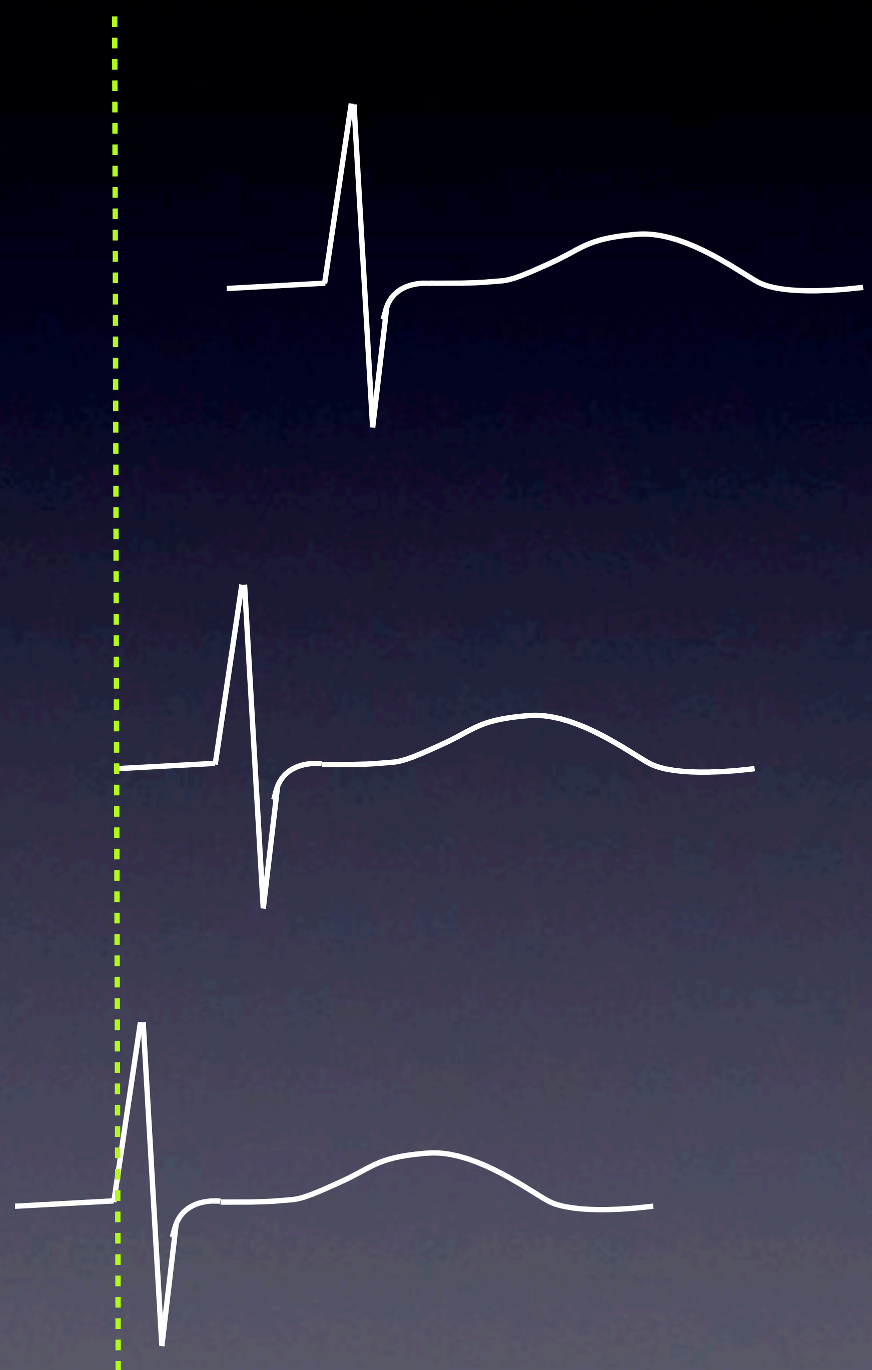

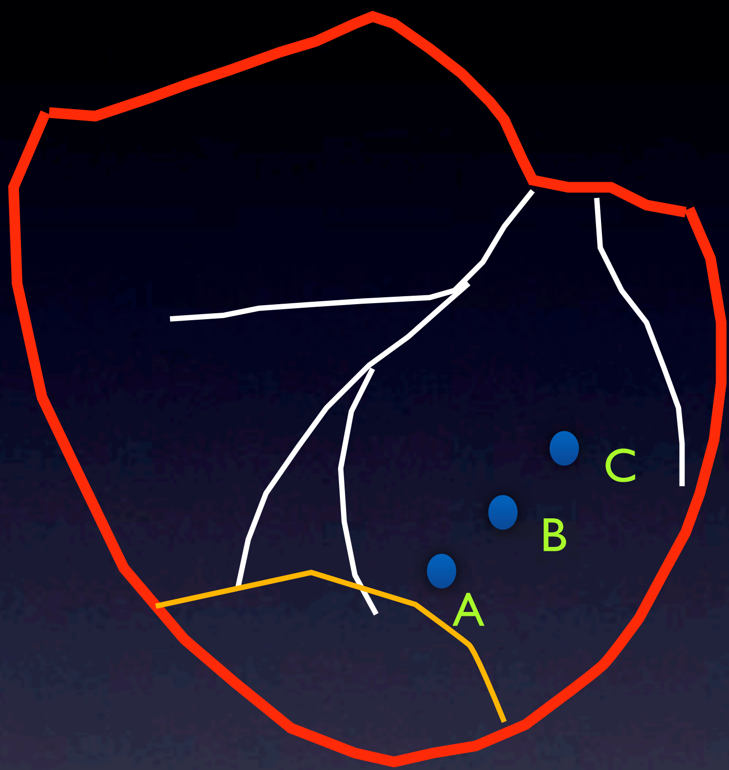

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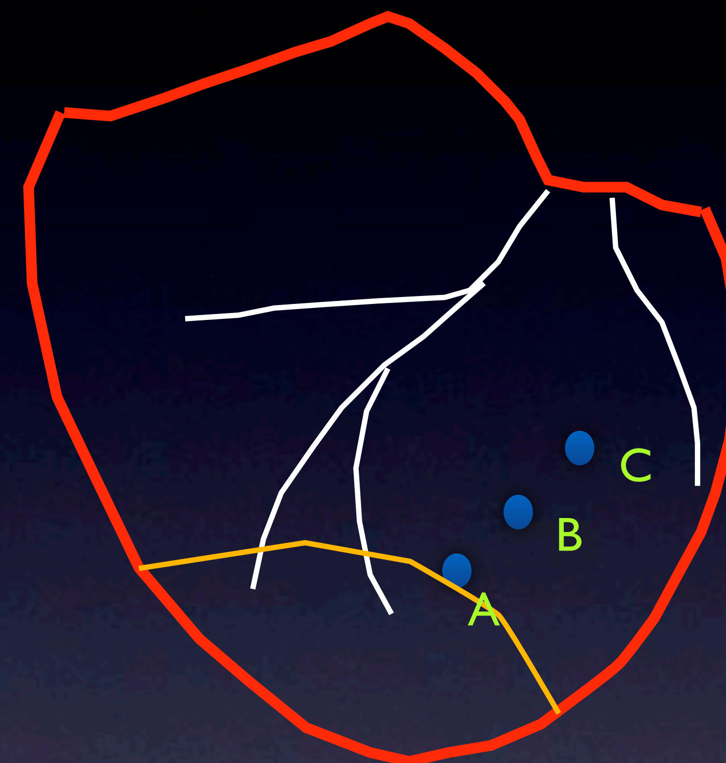

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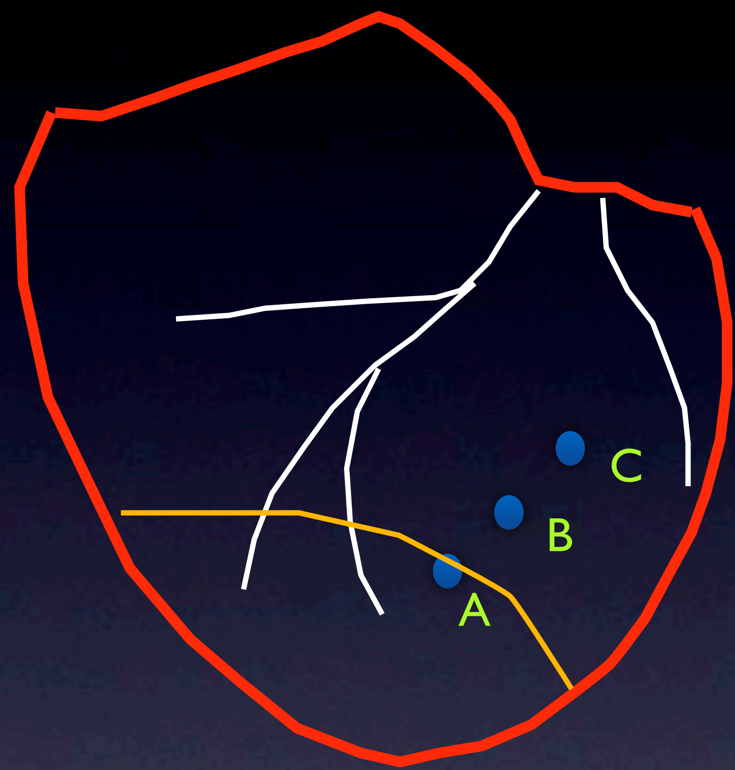

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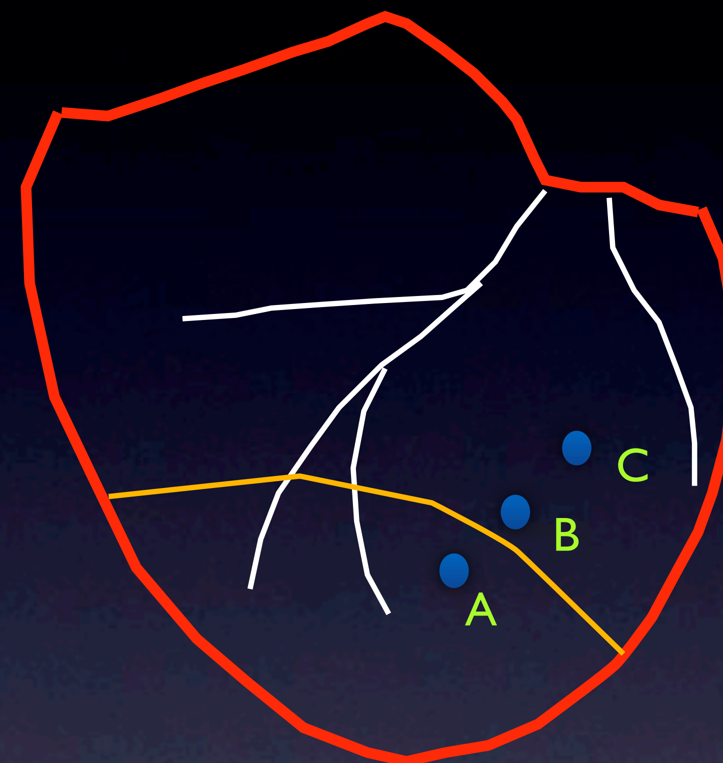

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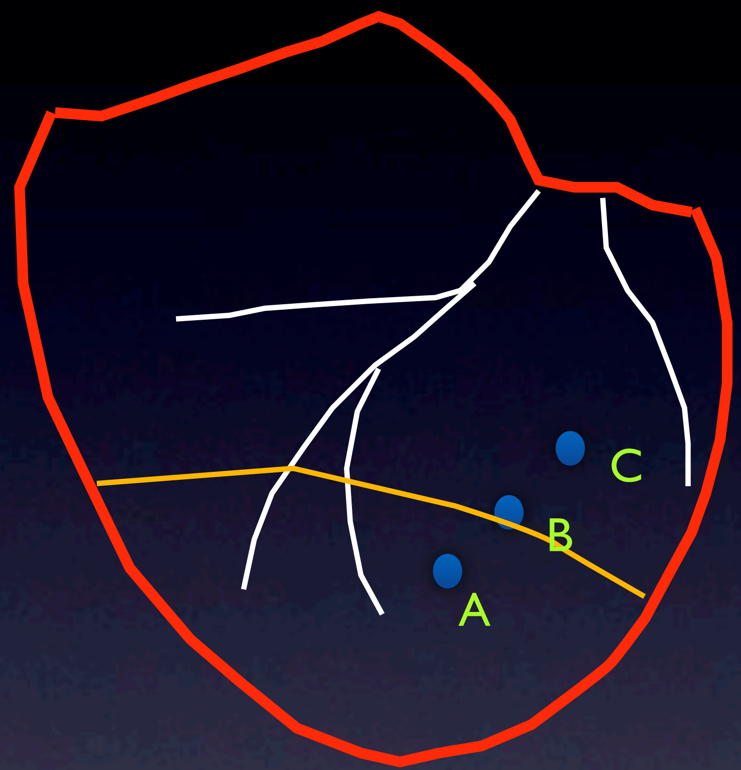

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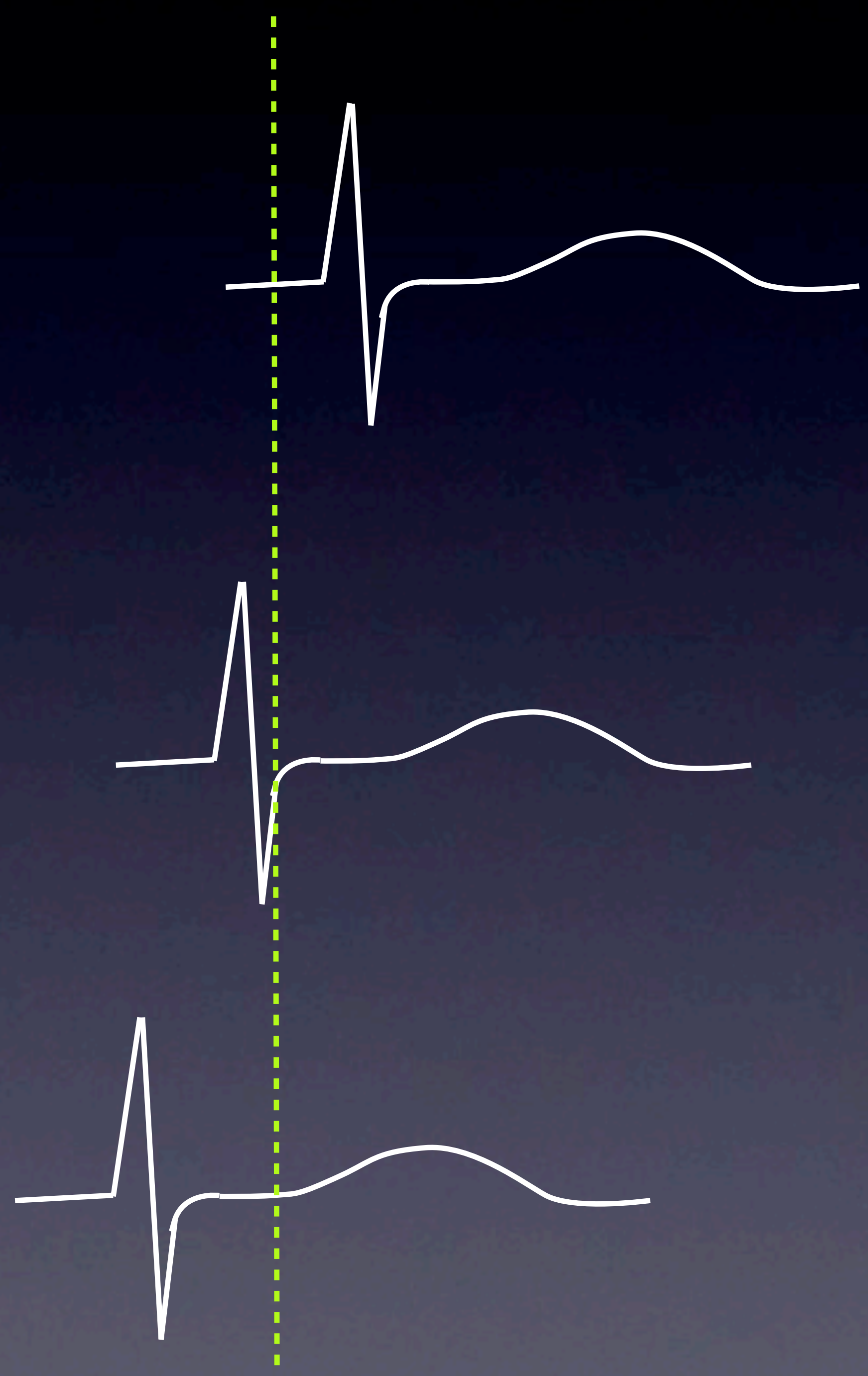

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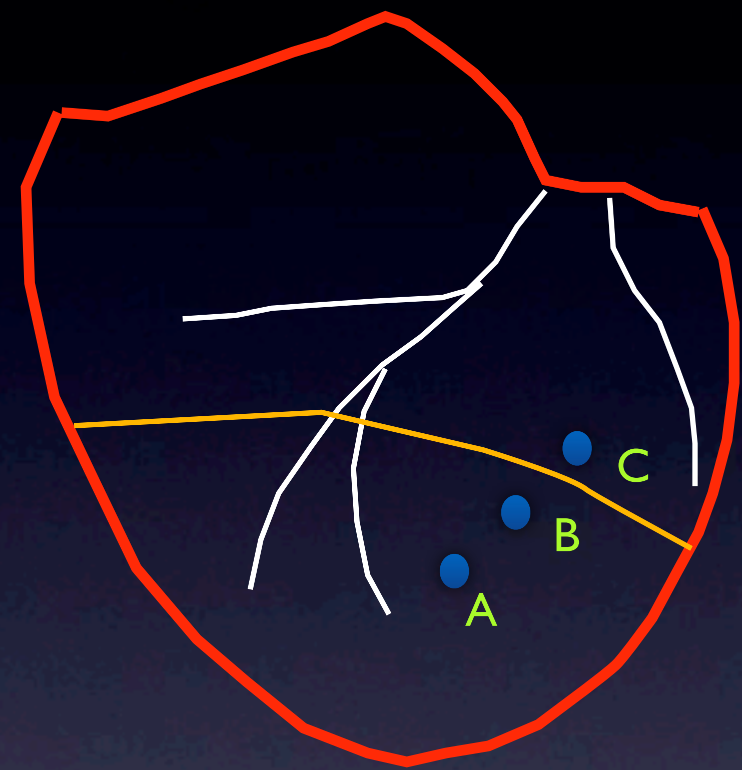

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Interpolation

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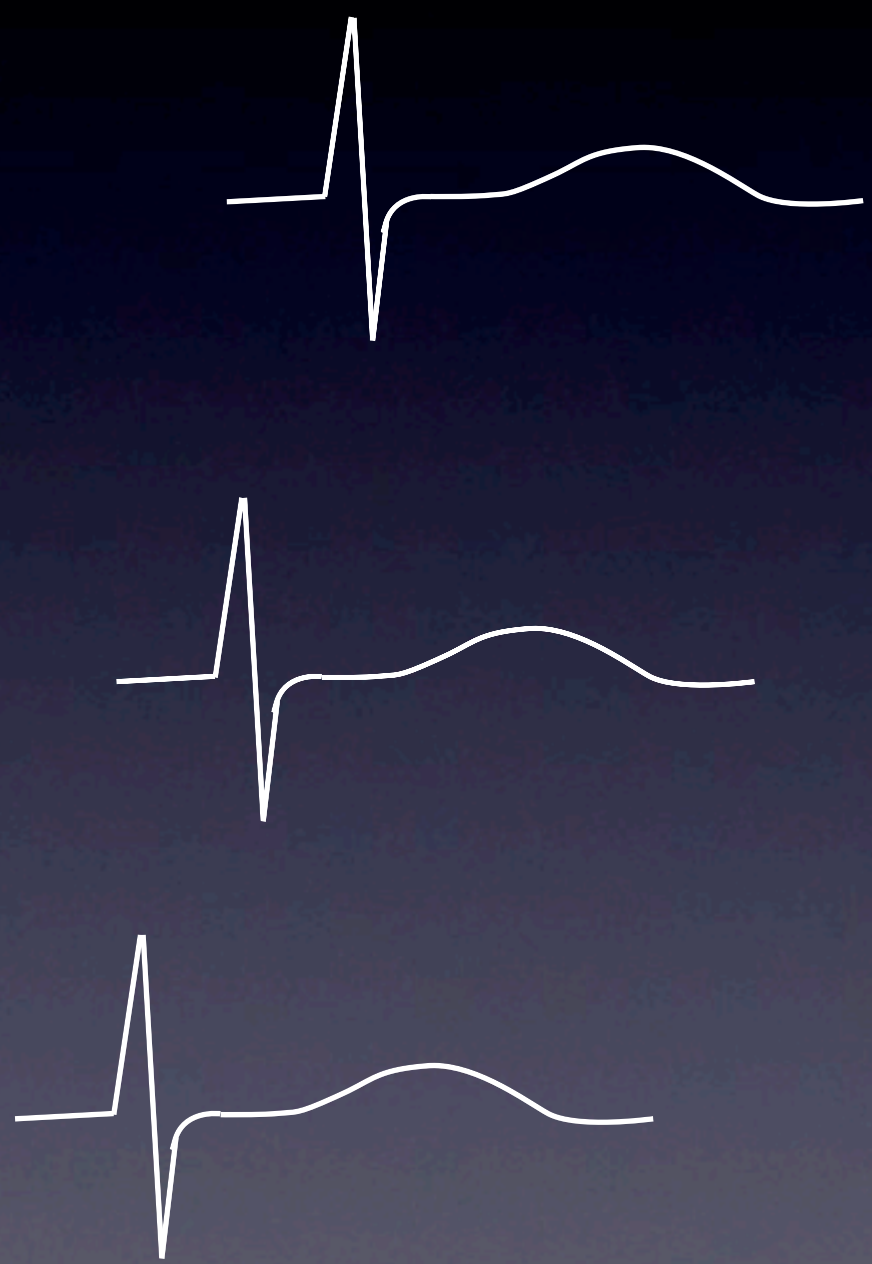

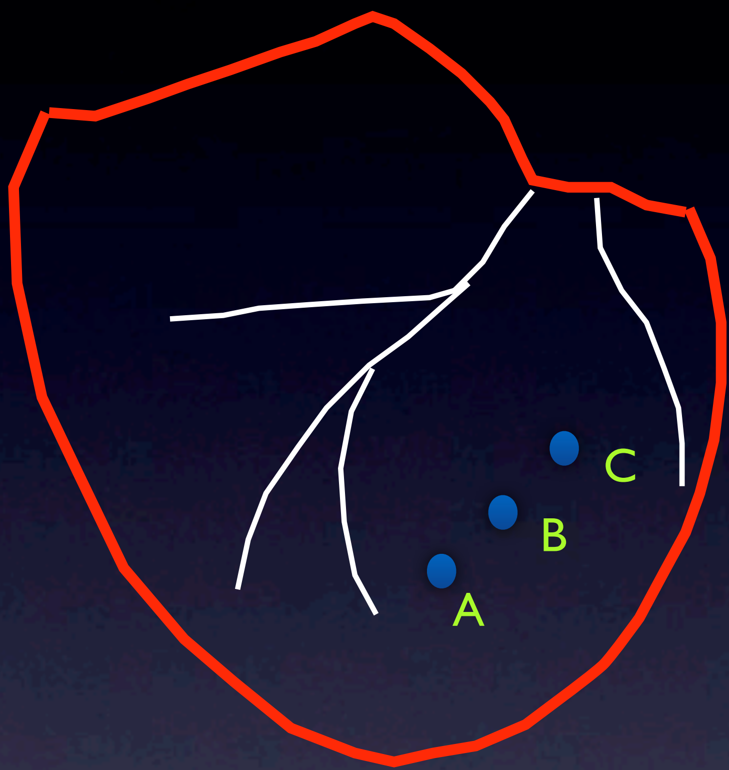

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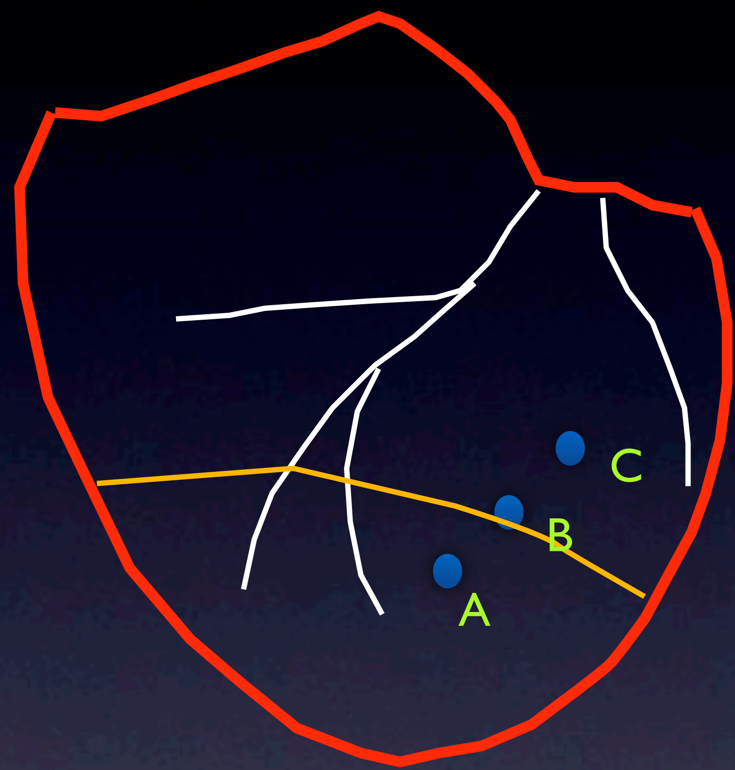

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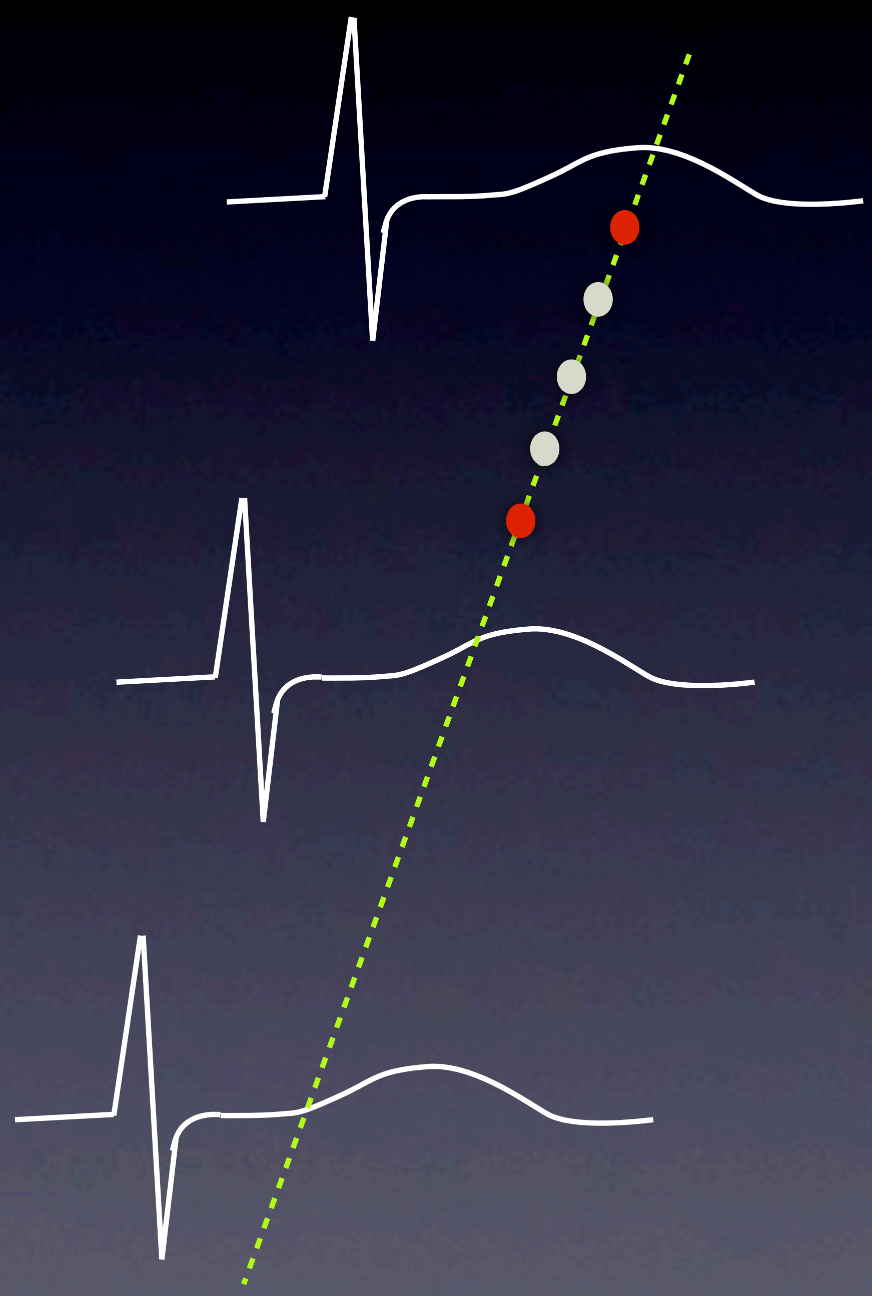

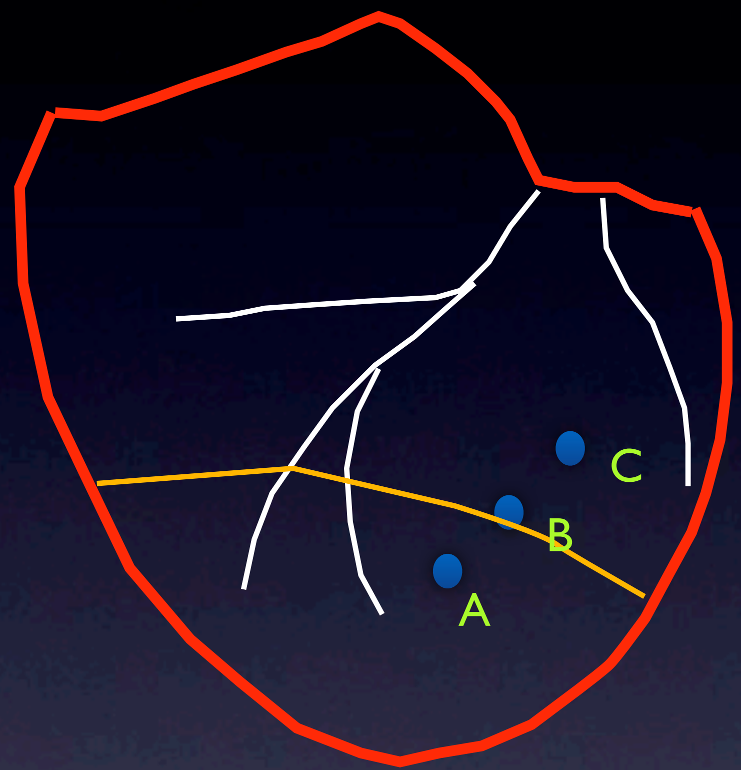

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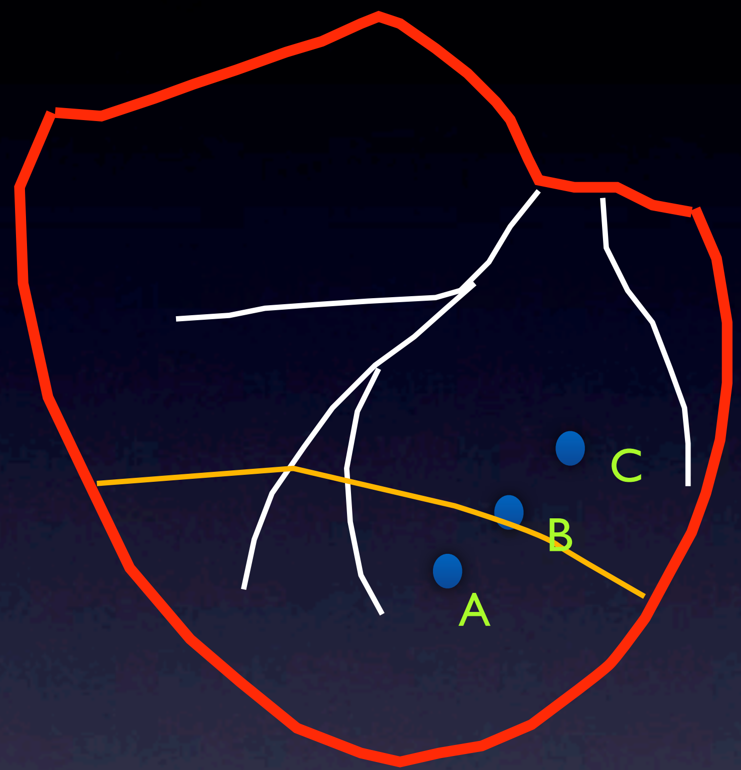

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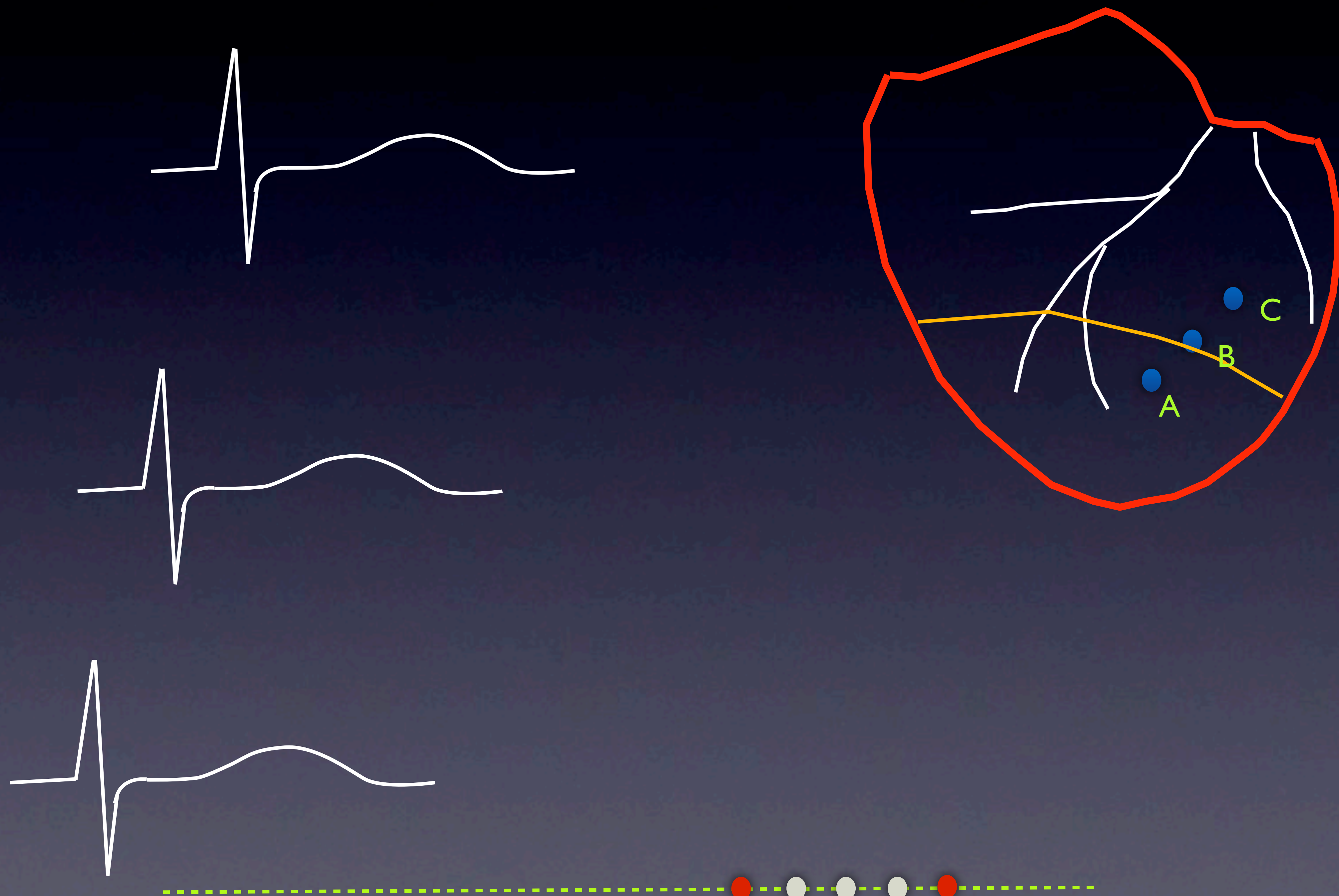

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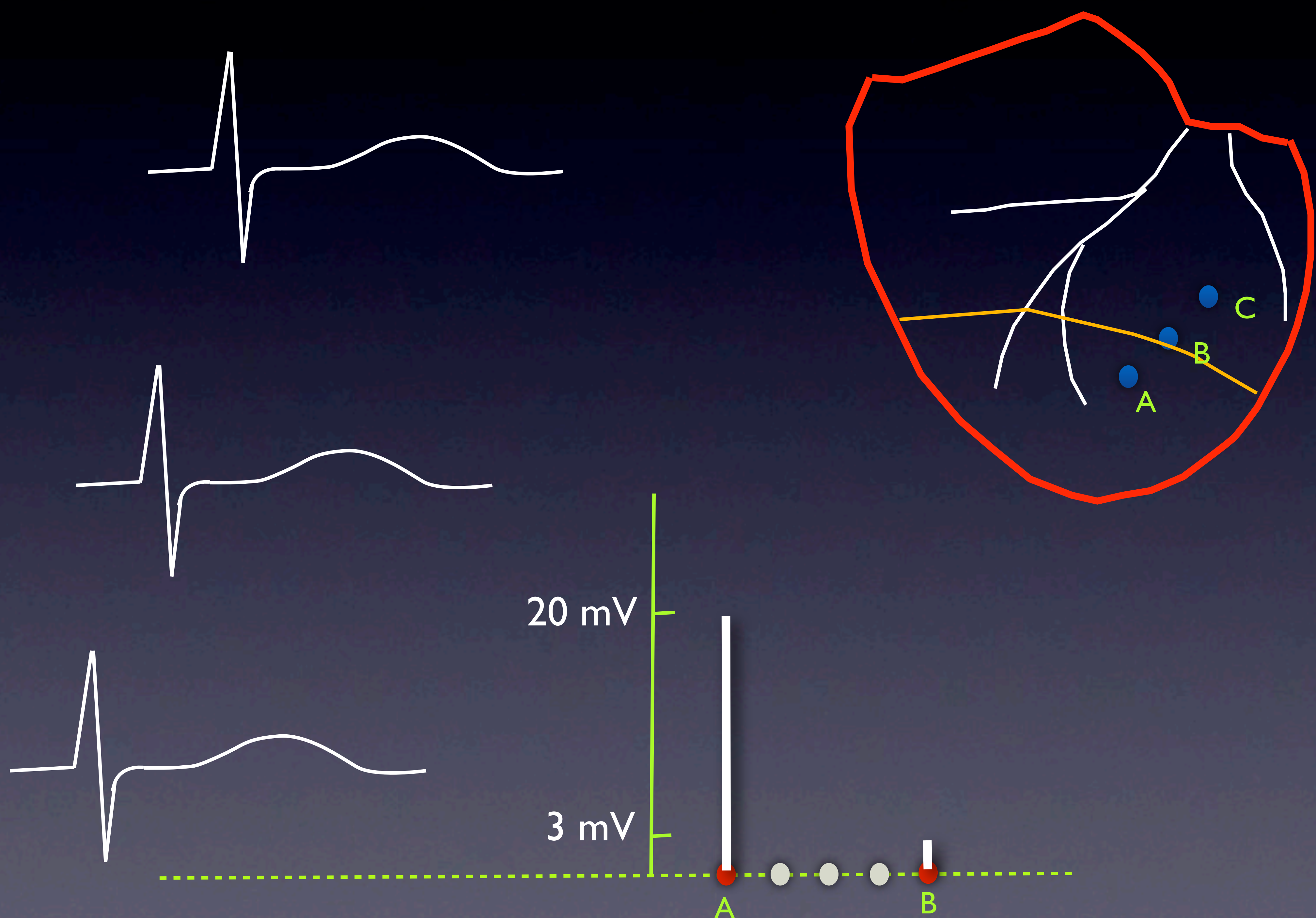

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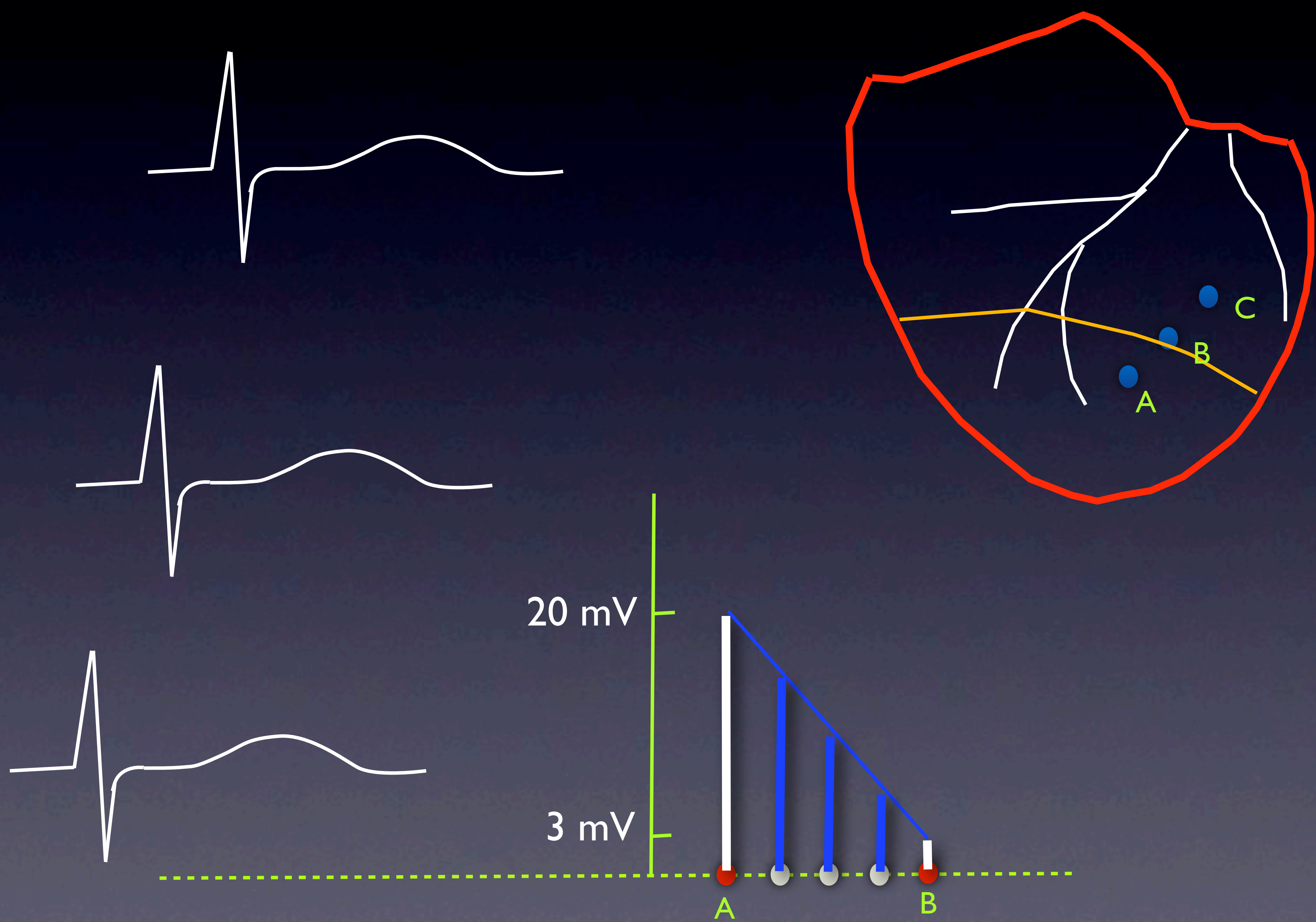

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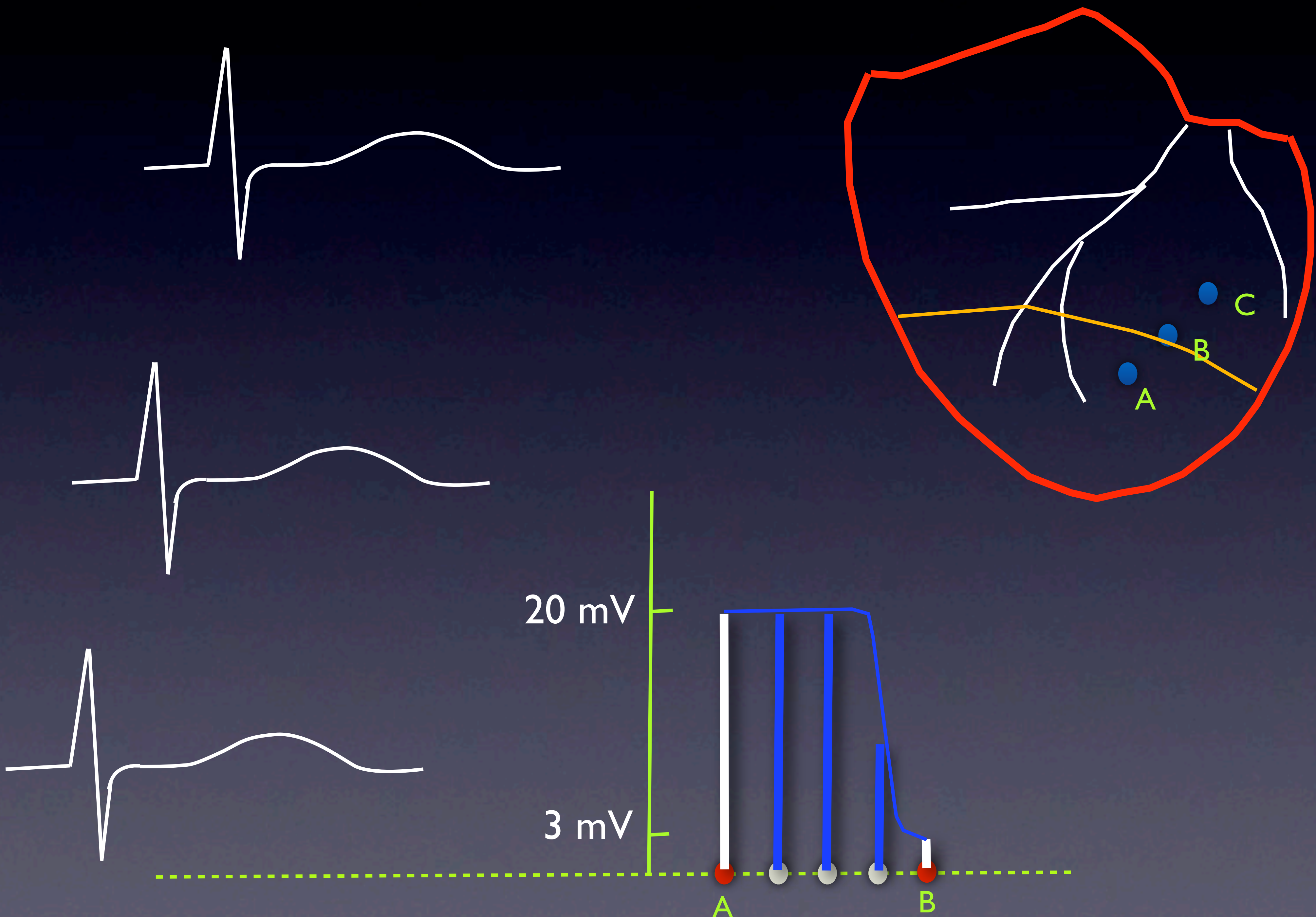

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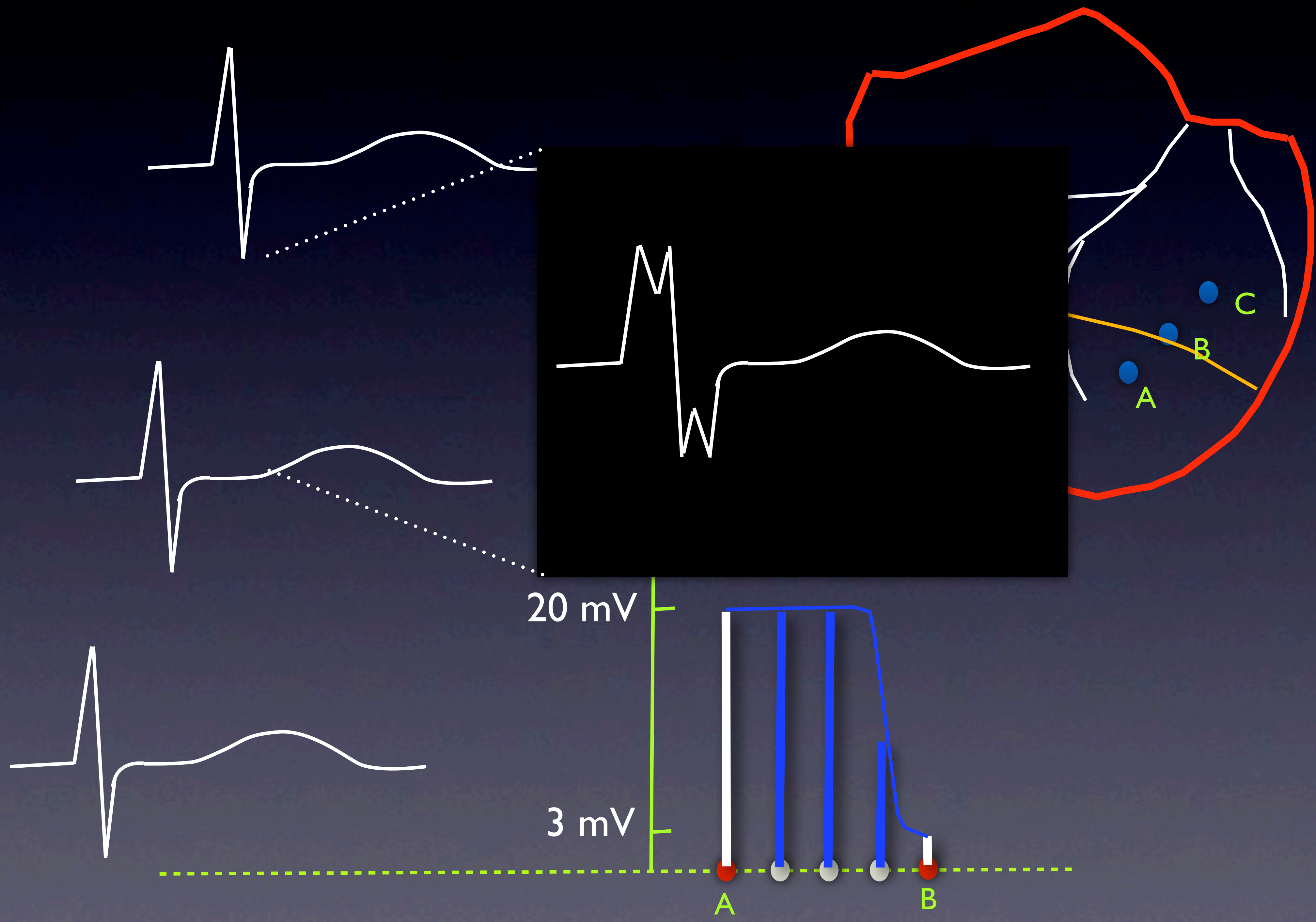
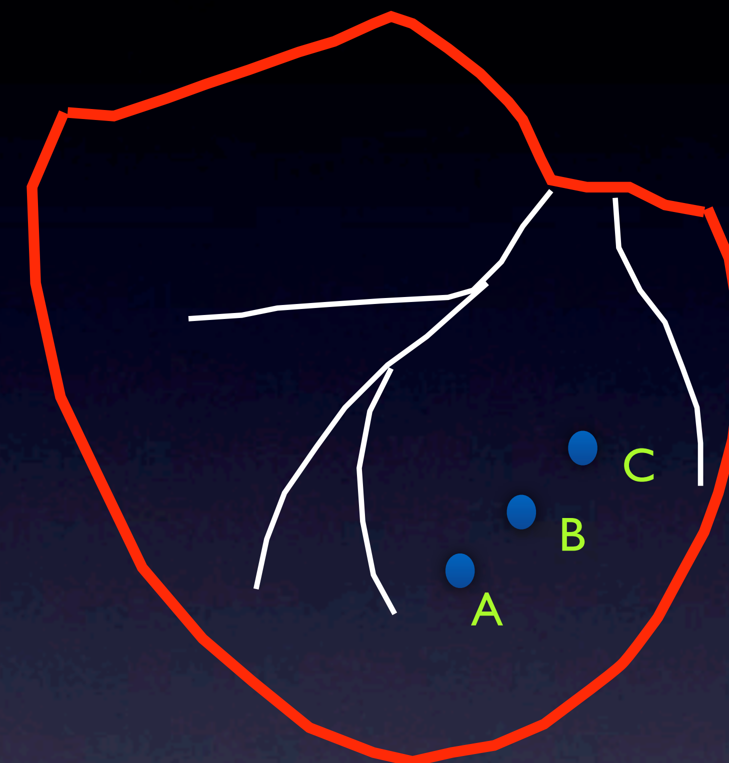


Wave Equation Based



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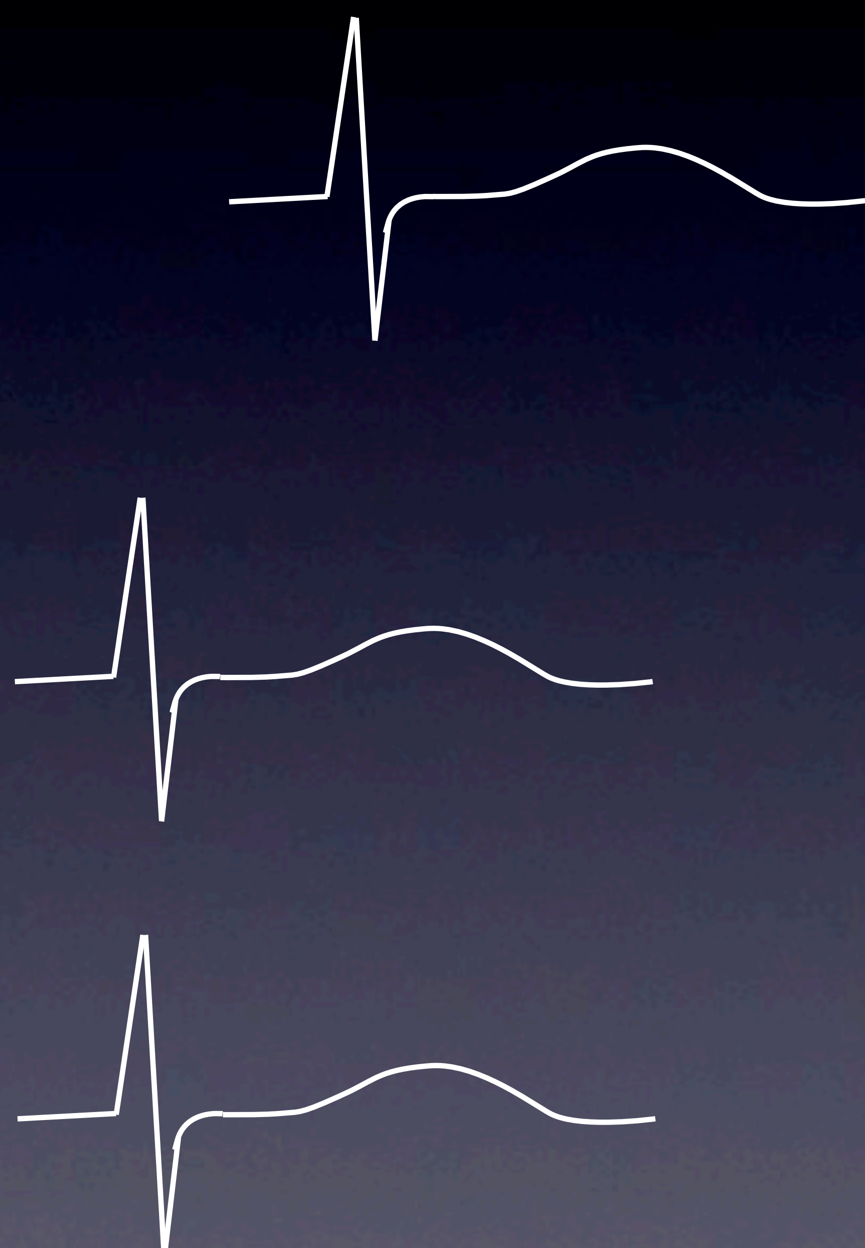

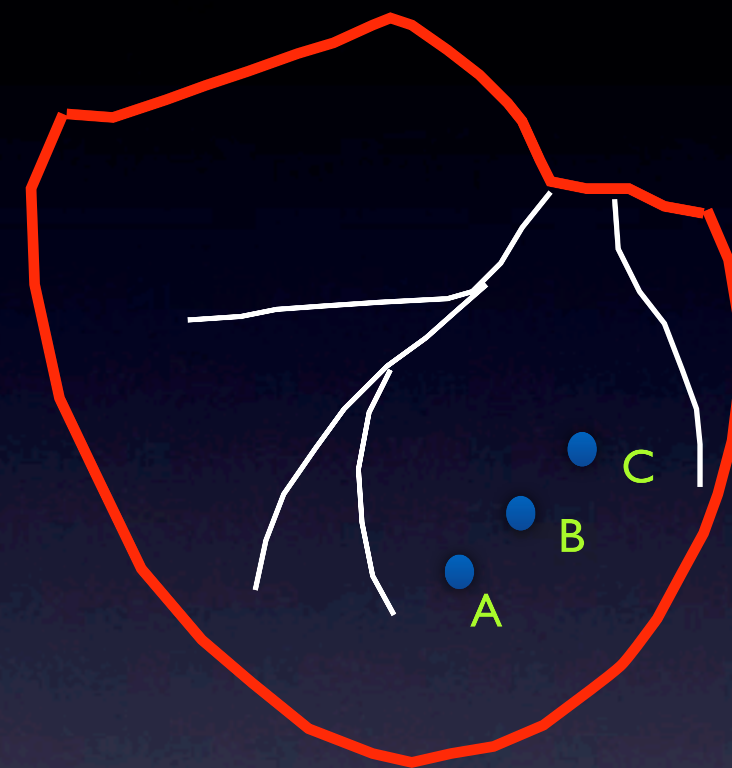

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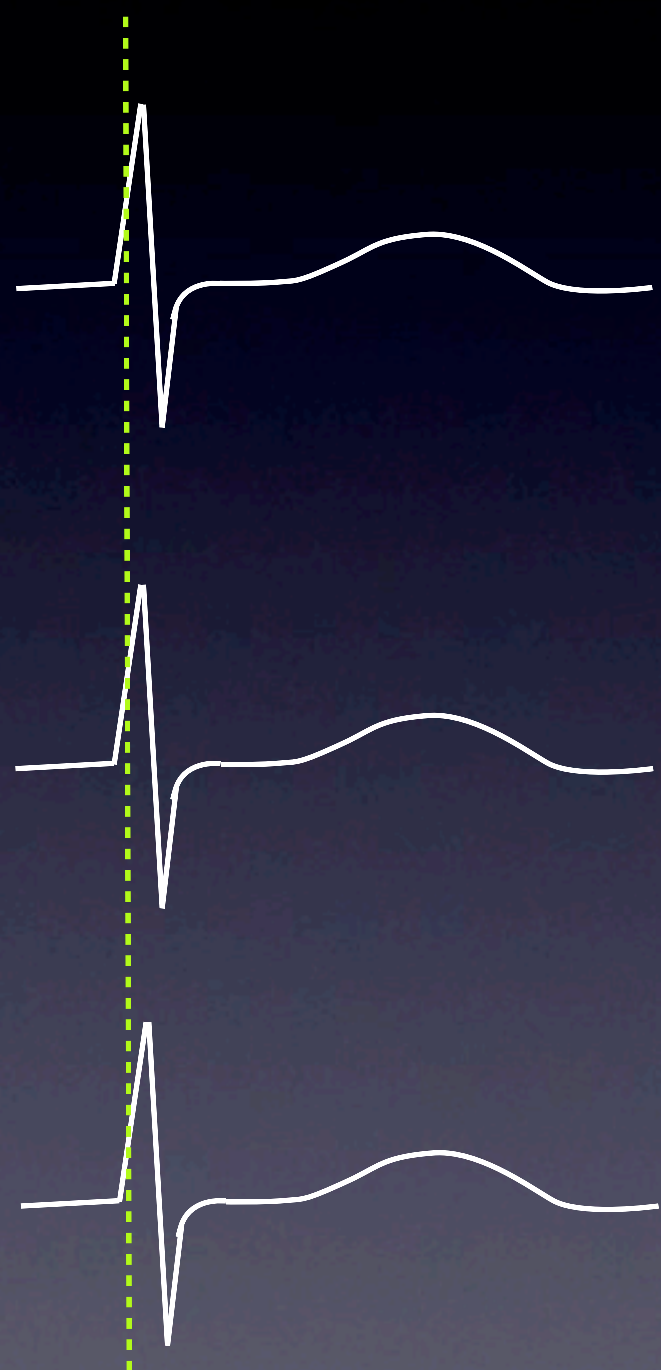

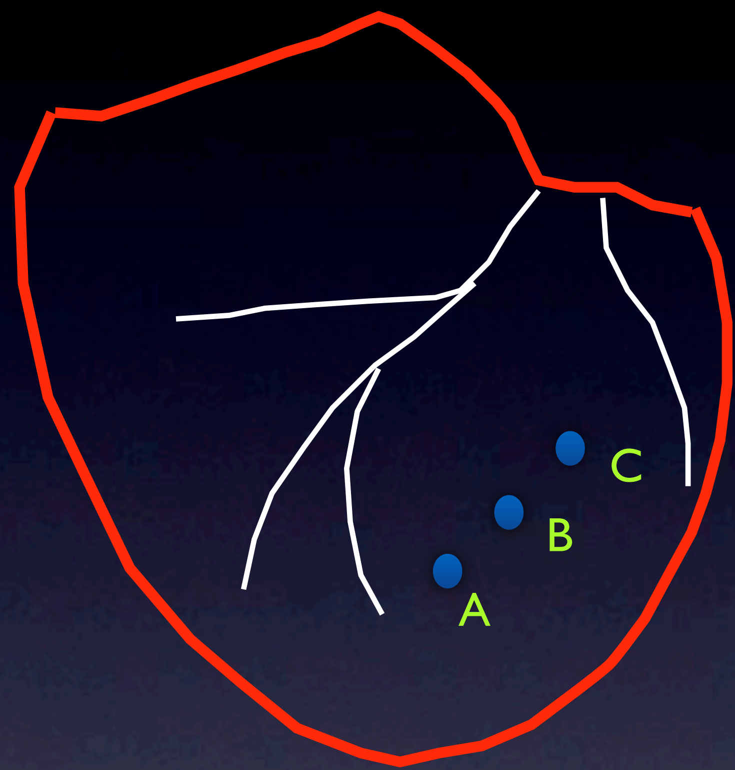

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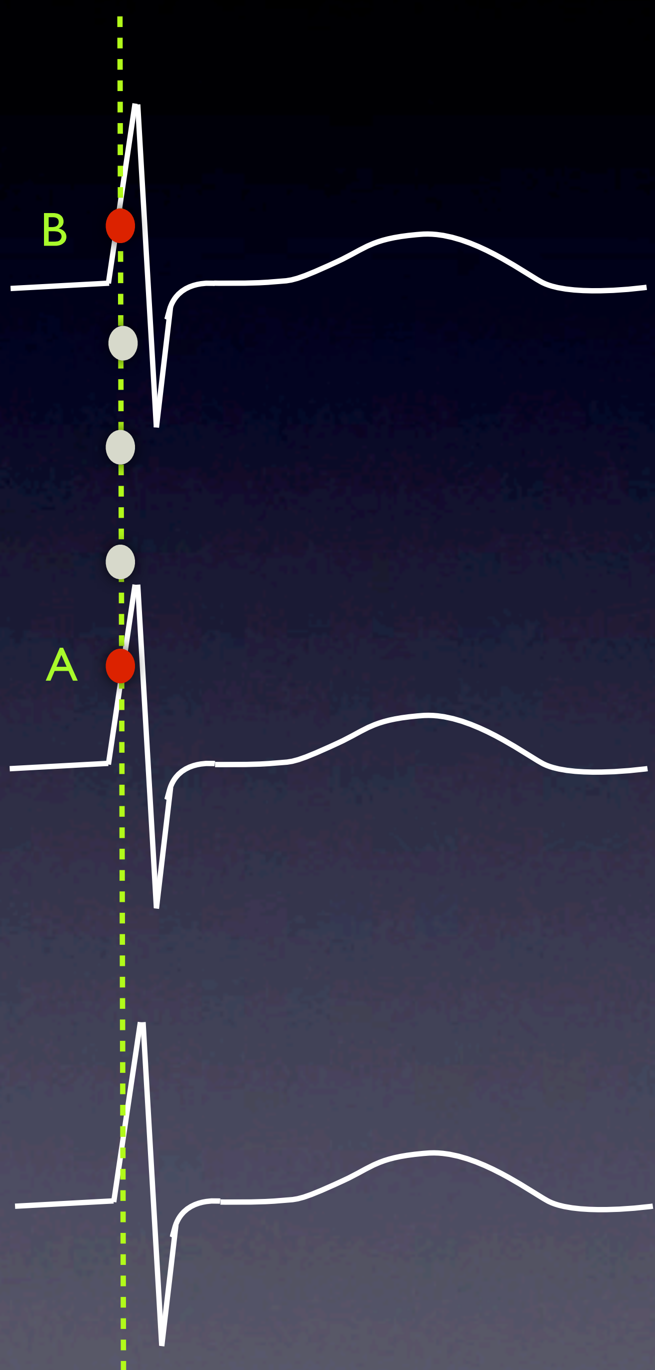

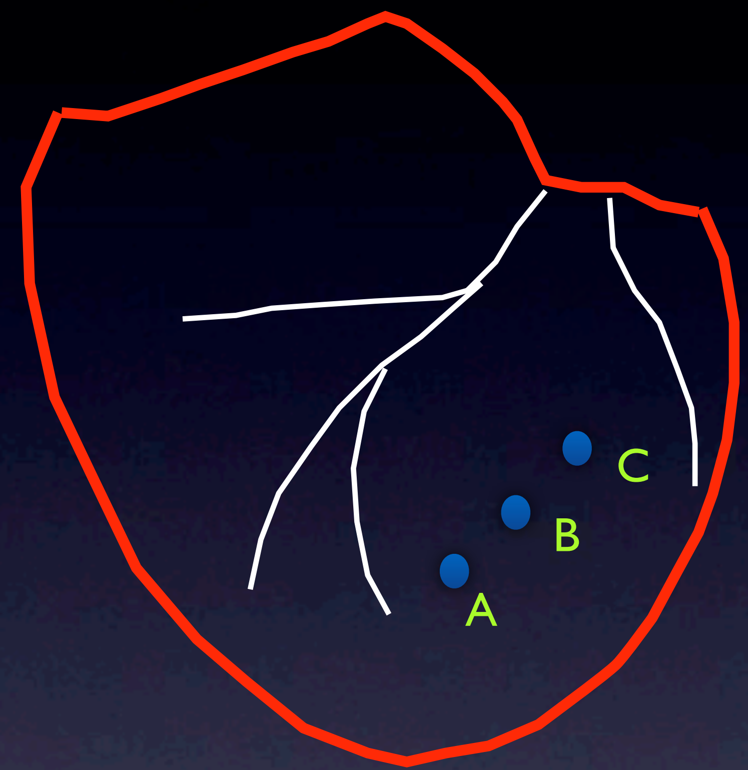

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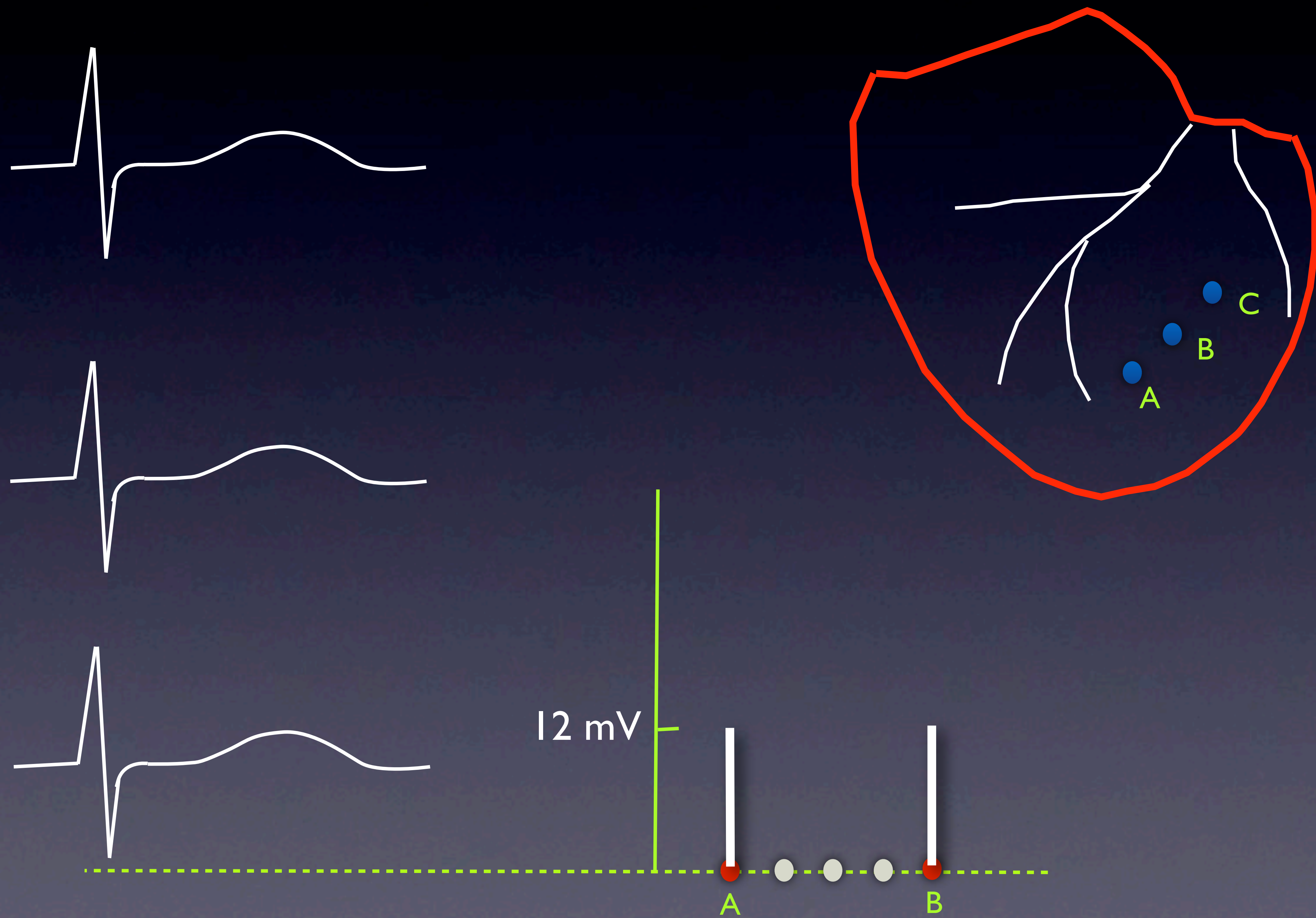

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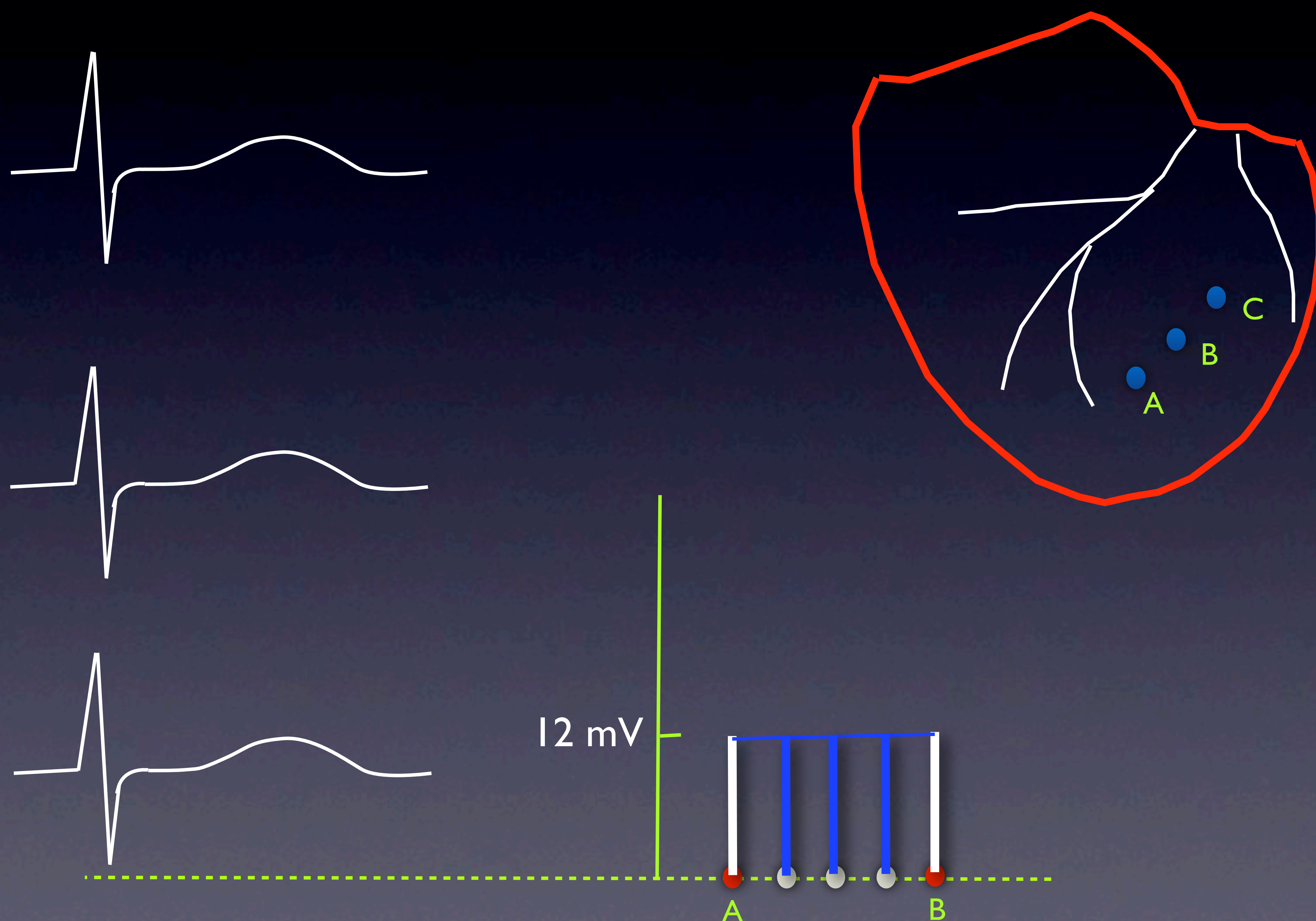

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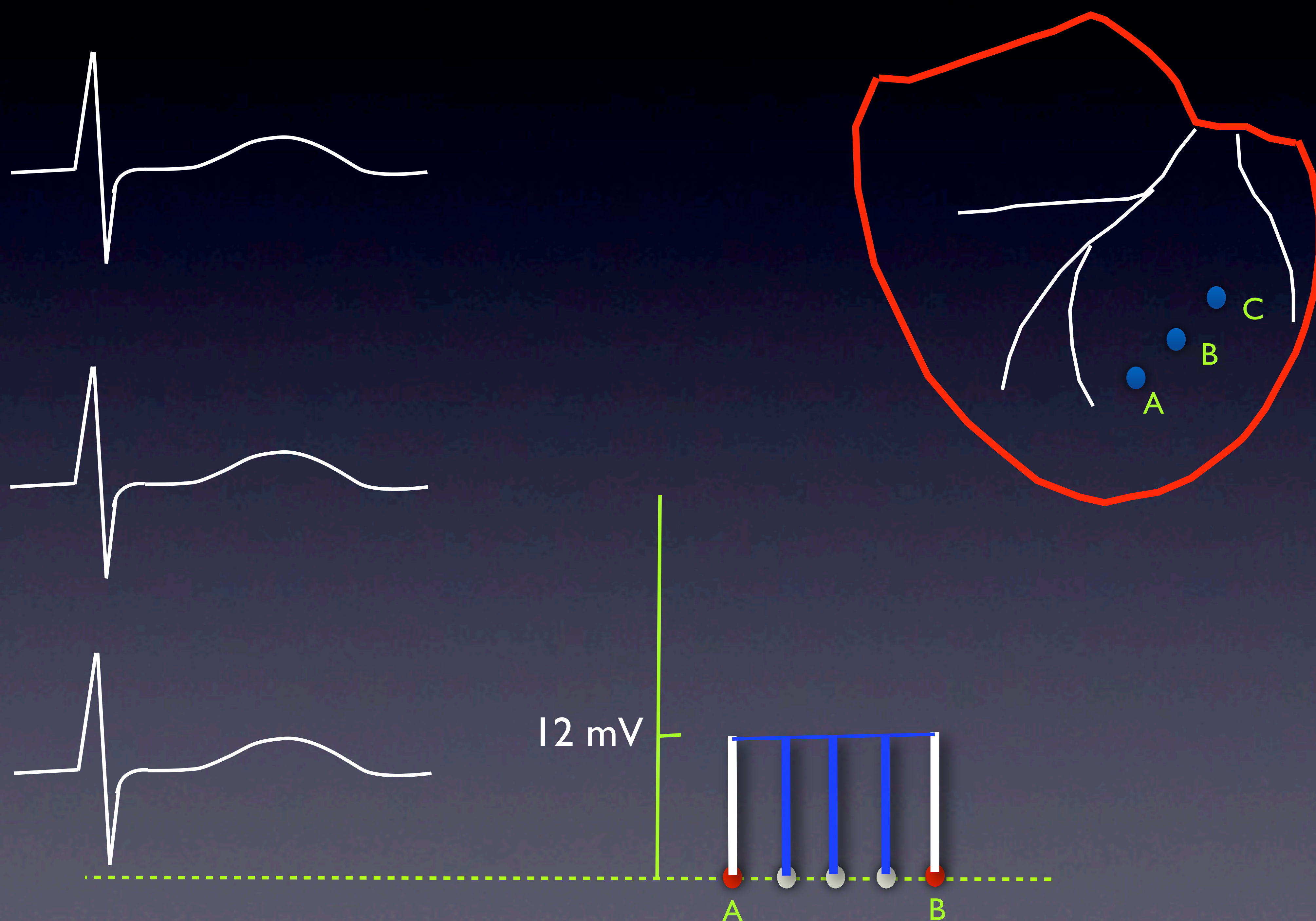

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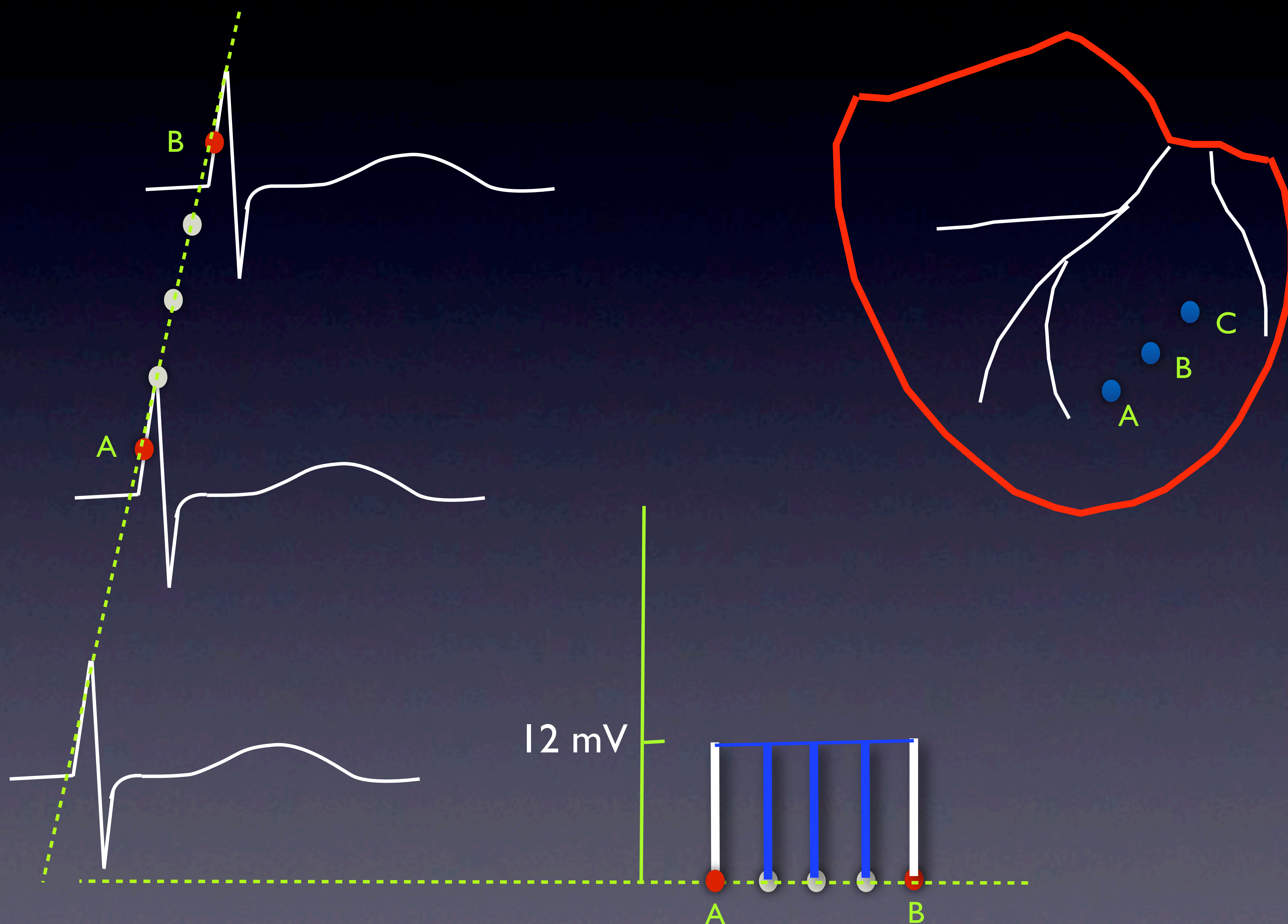

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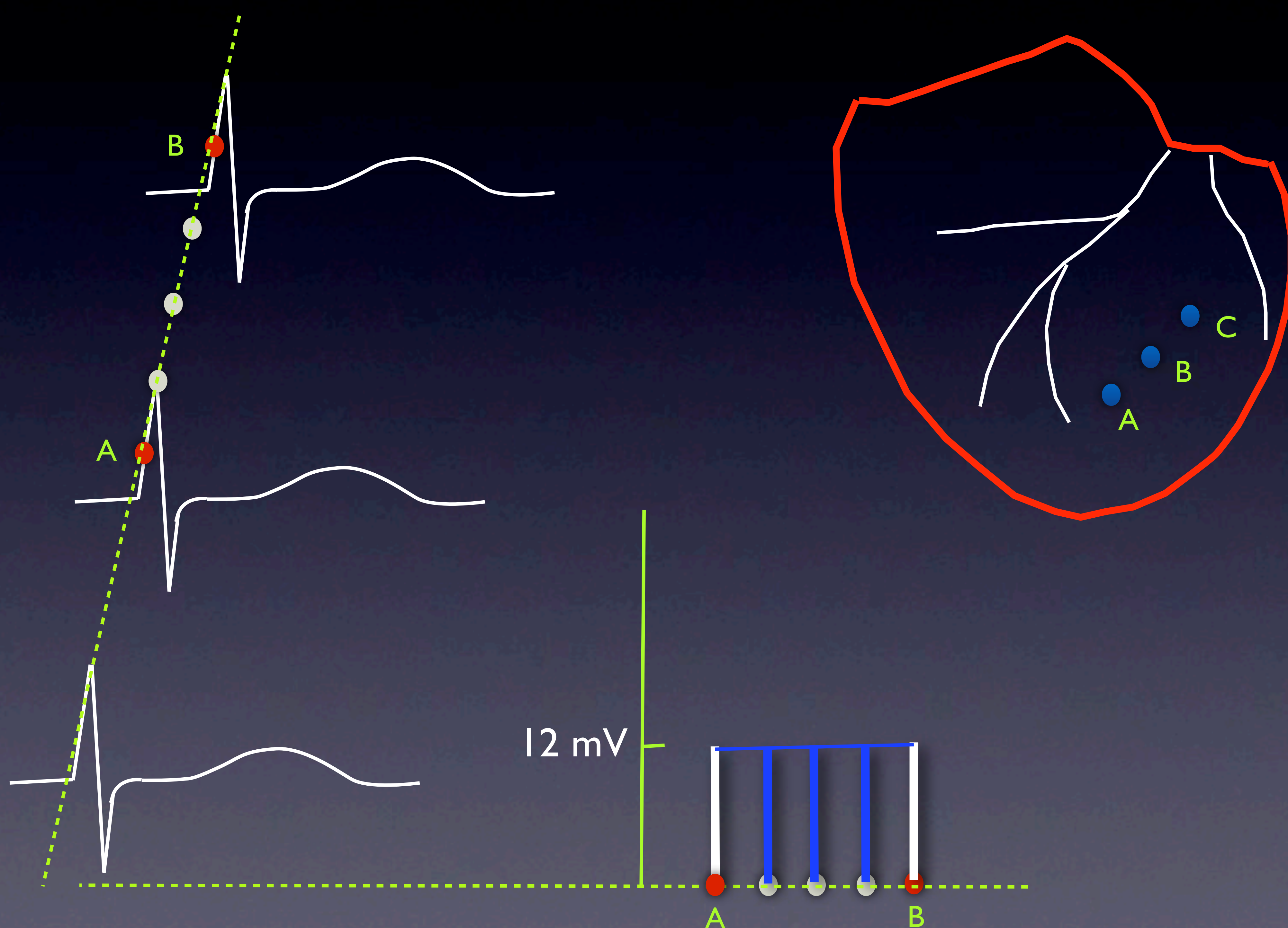
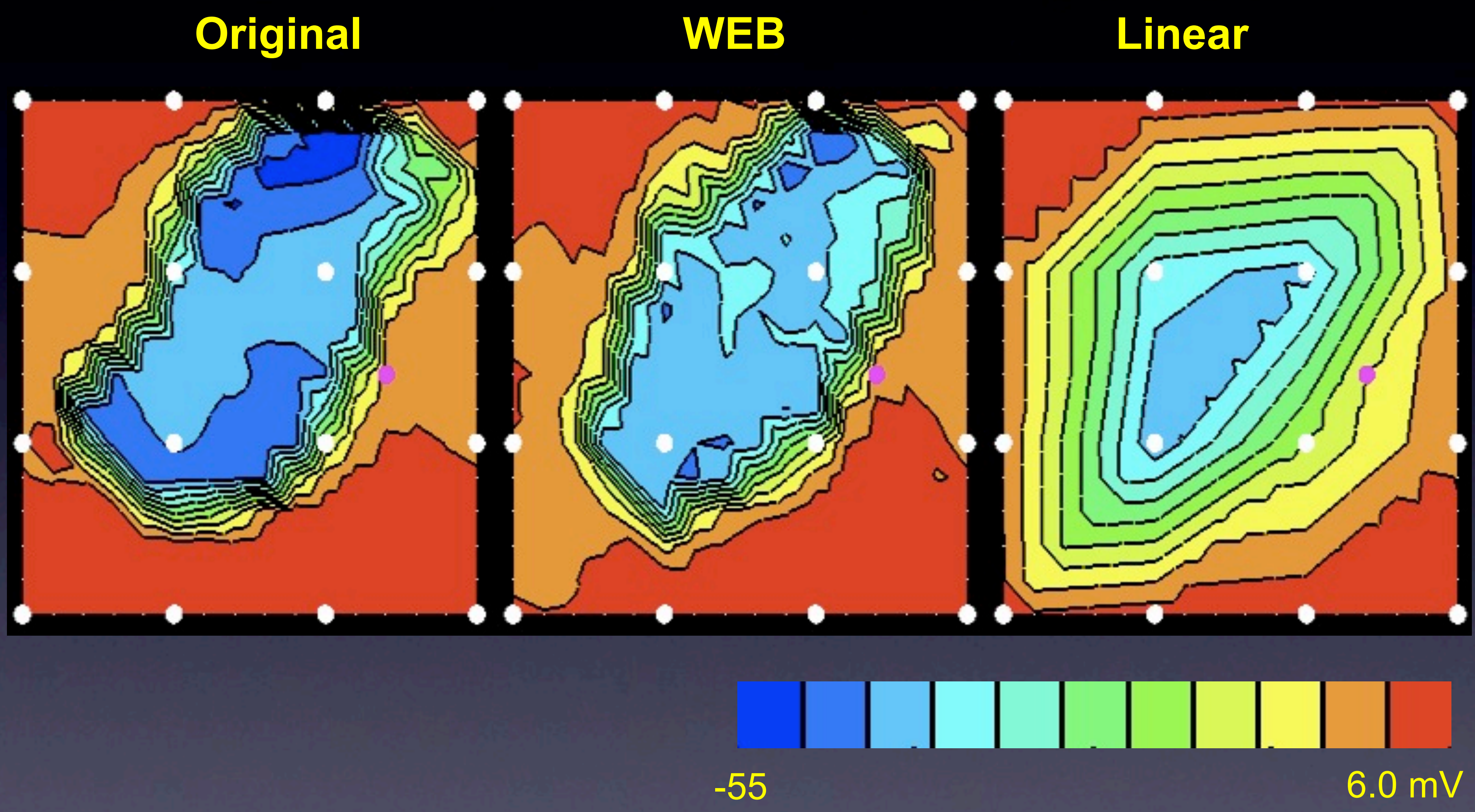


Surface WEB Interp.



Implementation

Create test data set

Linear Interpolation

Laplacian Interpolation

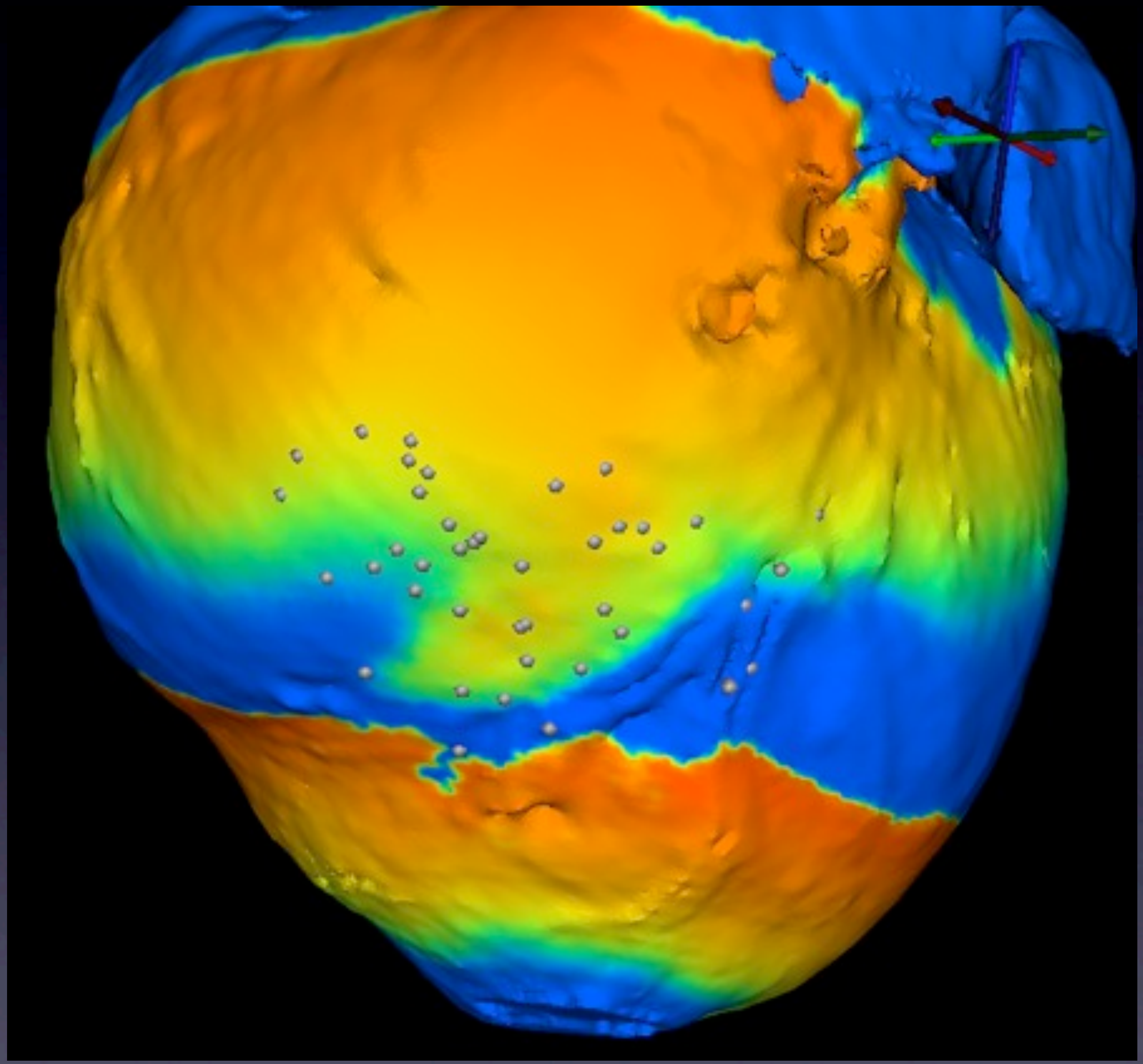
WEB Linear and Laplacian Interpolation

- Time align data
- Interpolate potentials
- Interpolate activation times
- Re-align potentials by activation time

Evaluate results

Simulated Data

Dr. Natalia Trayanova



Simulated Data

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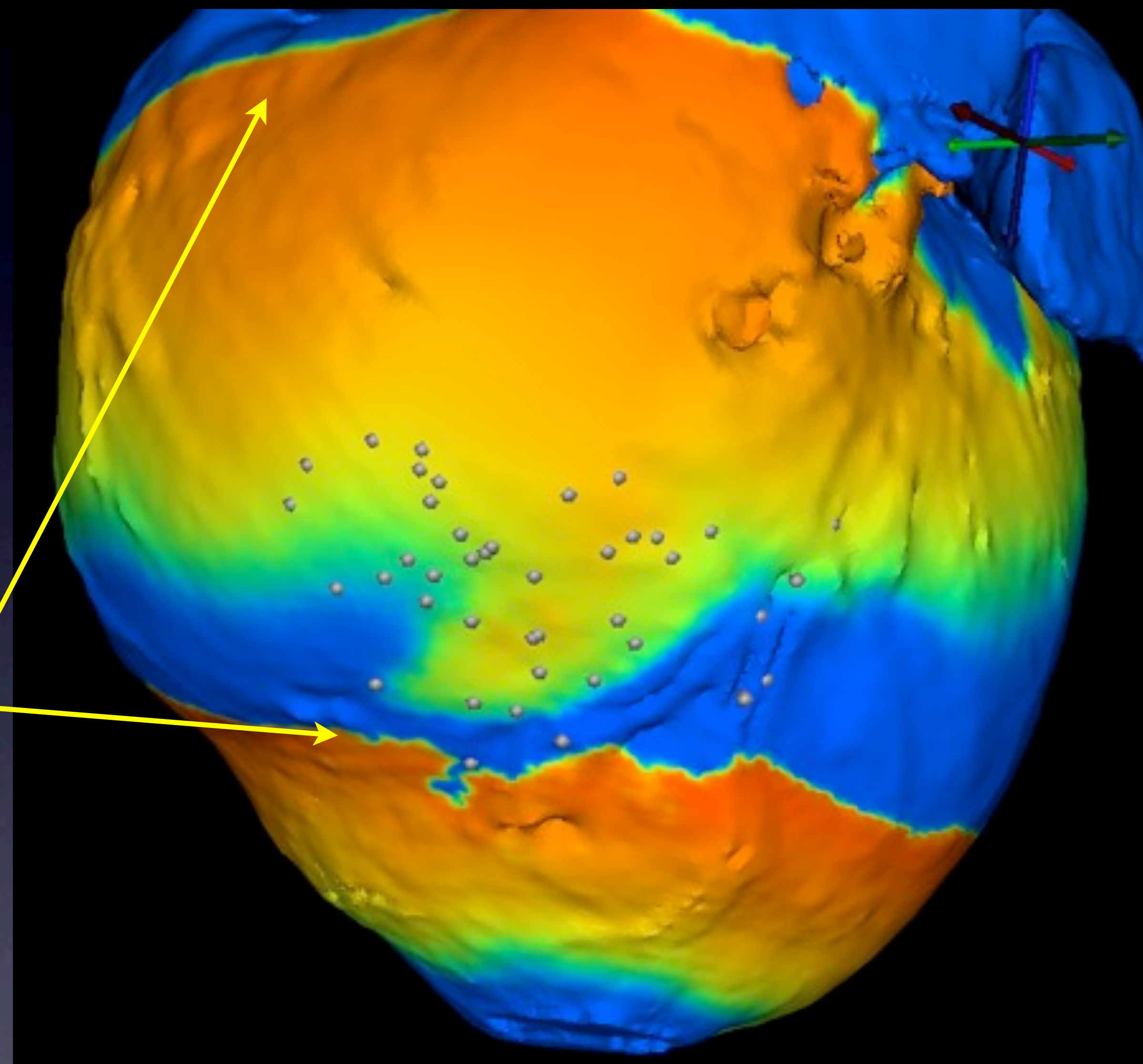
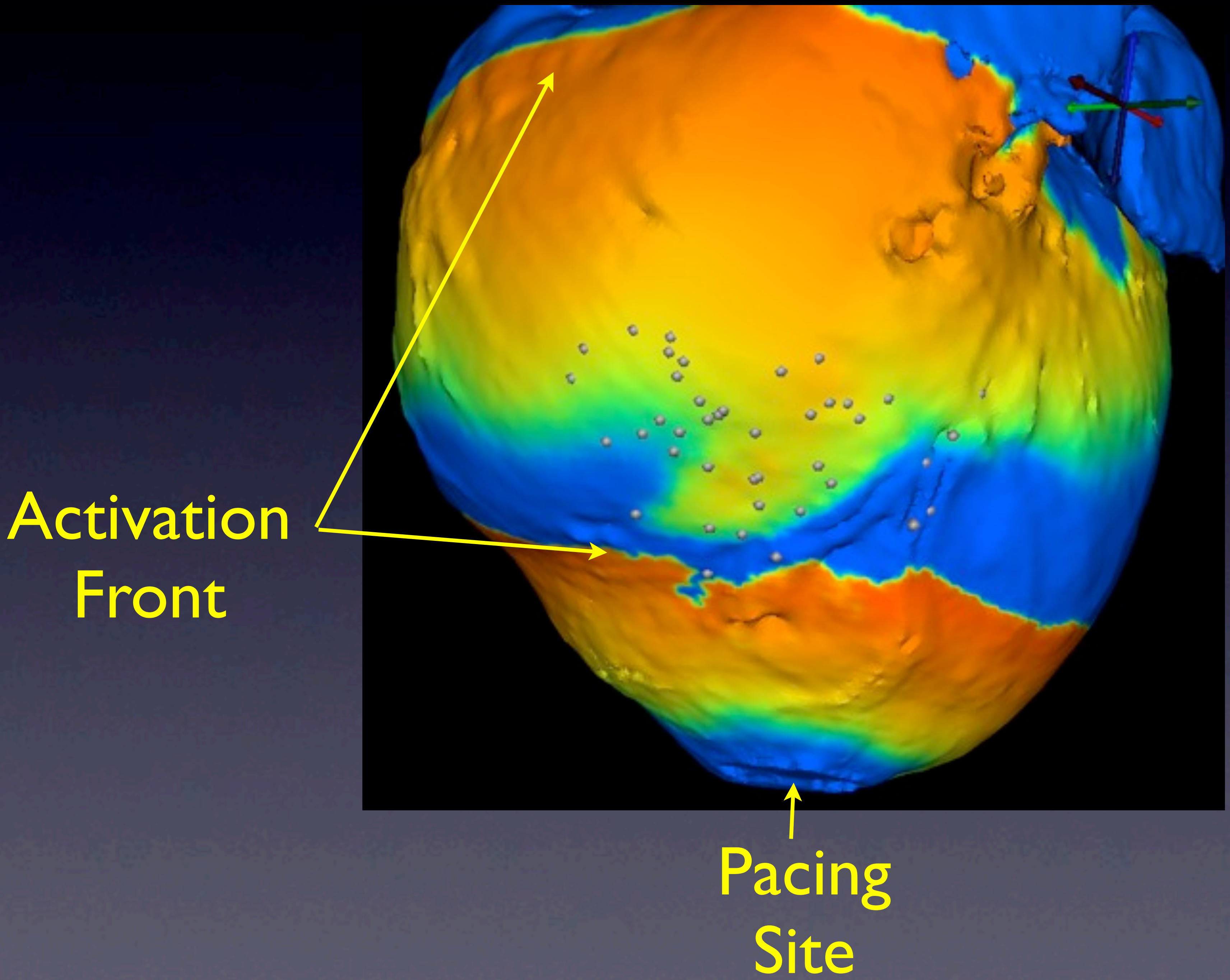


Activation Front

Simulated Data

Dr. Natalia Trayanova



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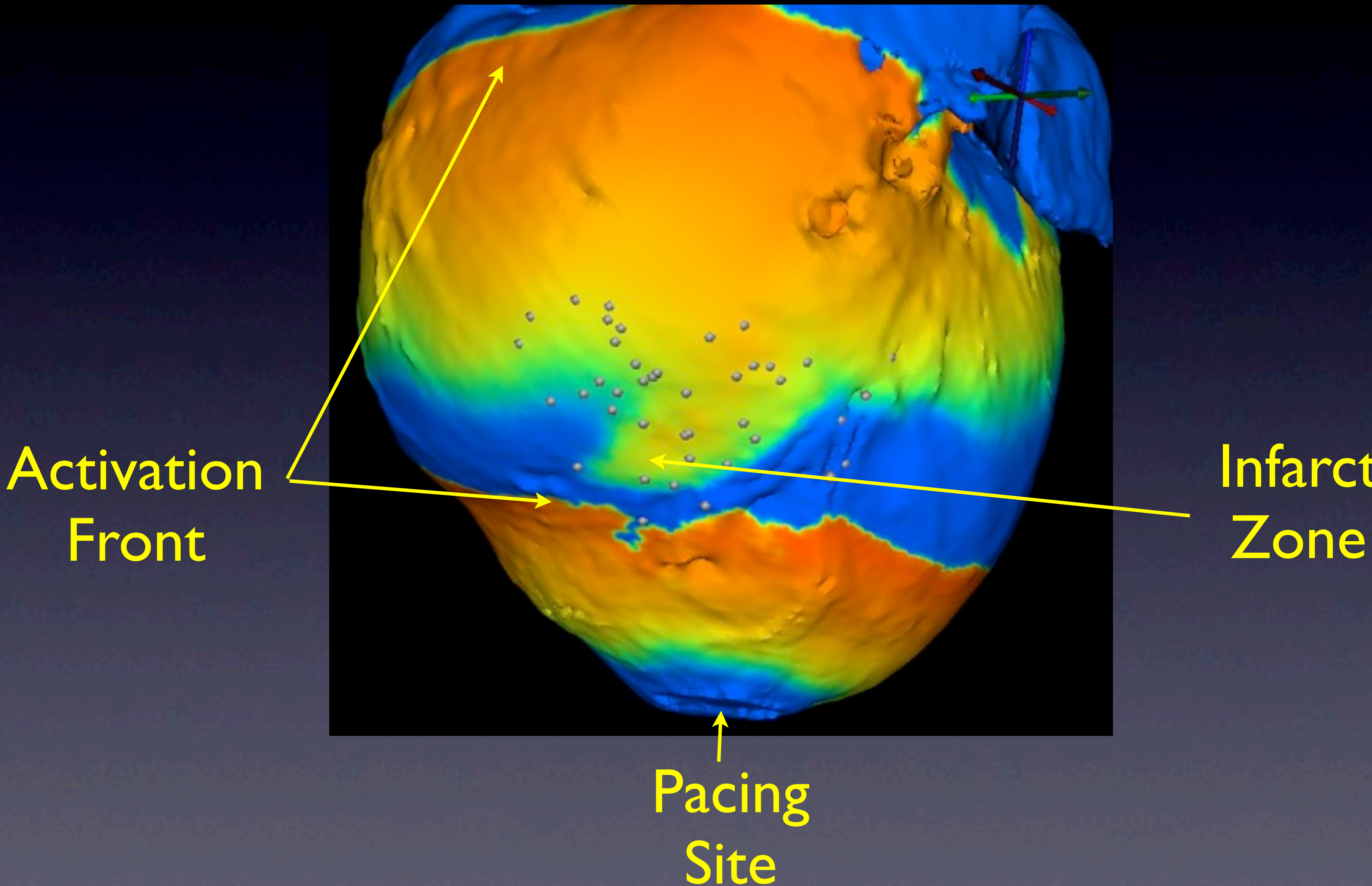
Simulated Data

Dr. Natalia Trayanova



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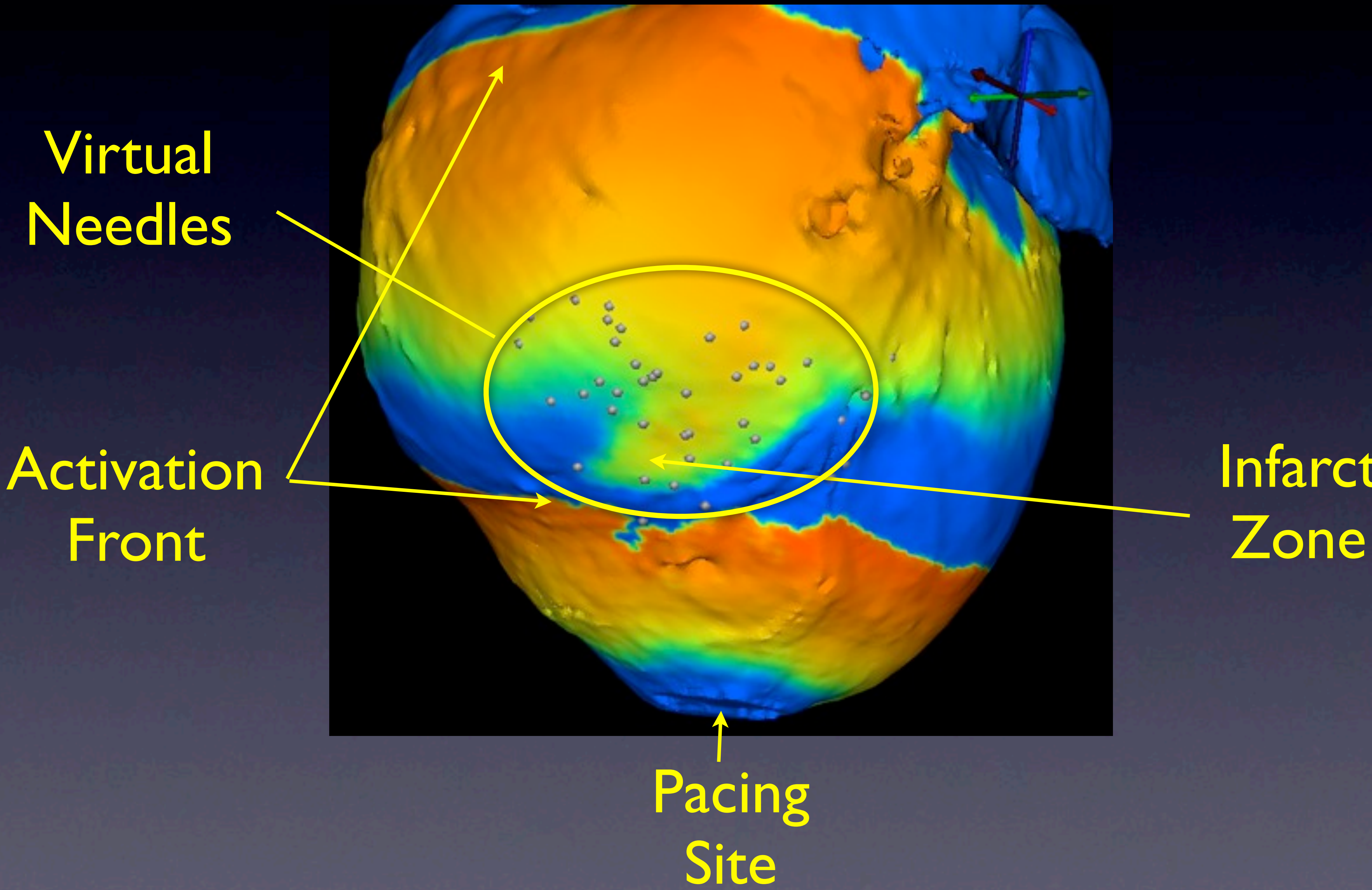
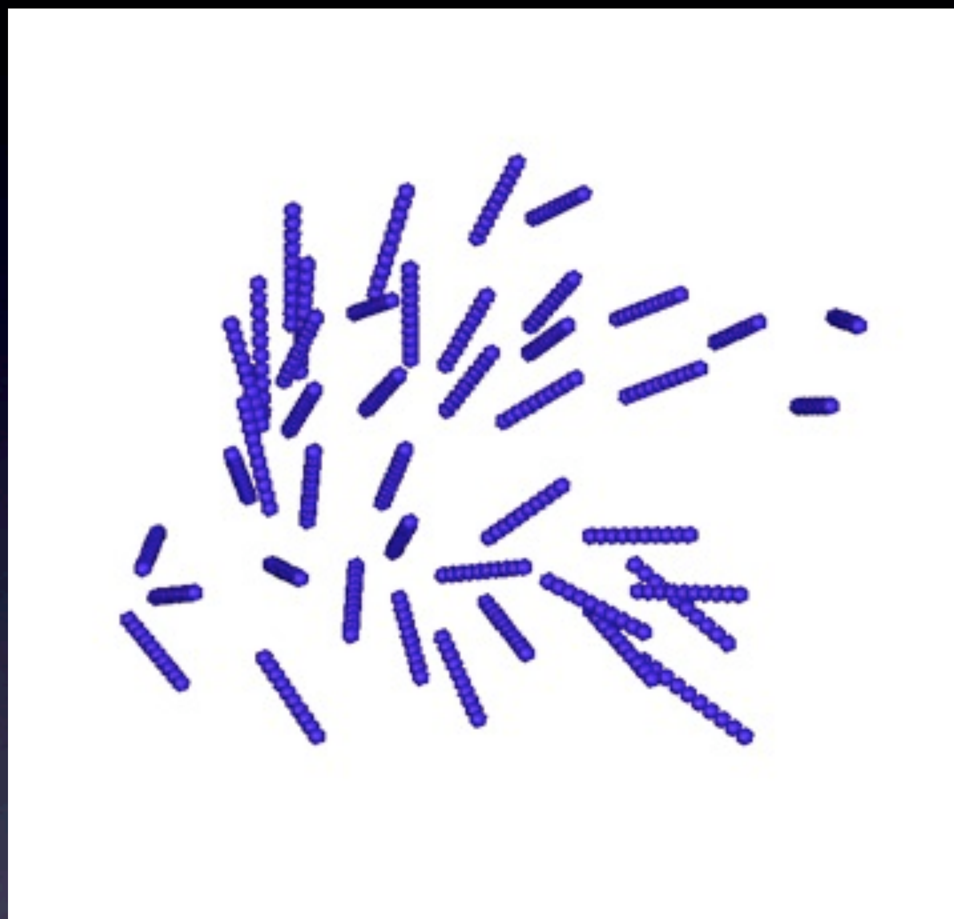
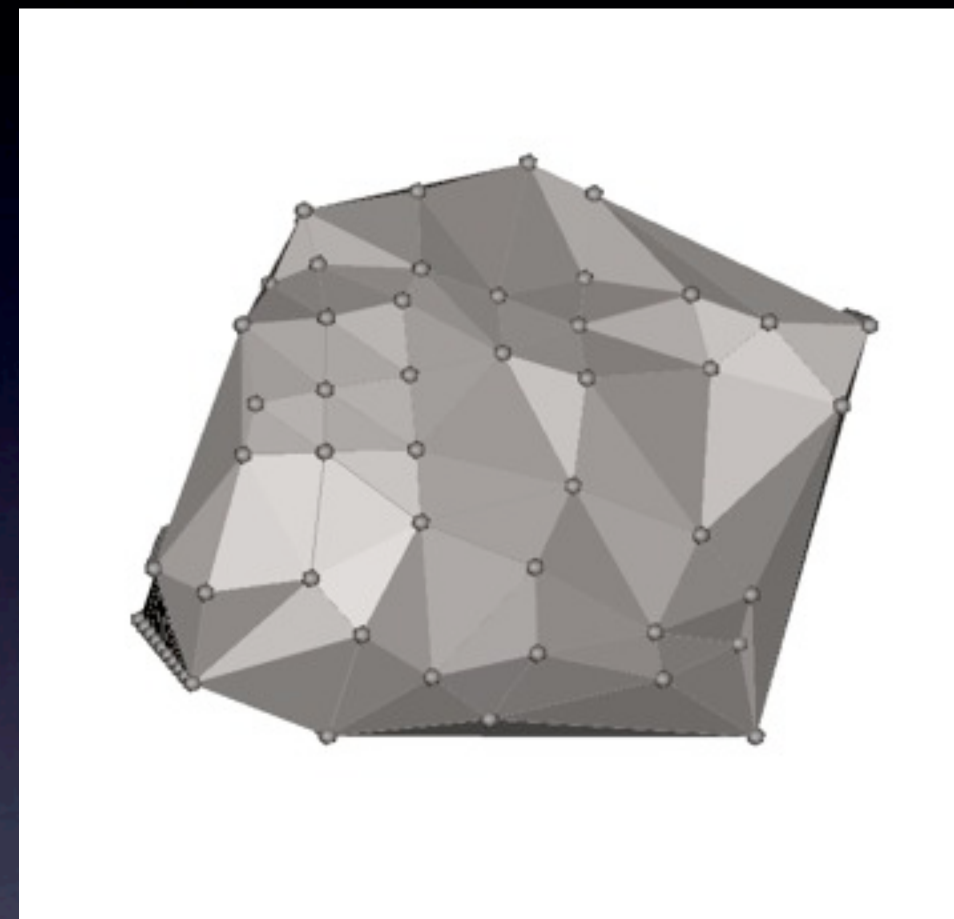


Linear Interpolation





Tetrahedral Mesh

Barycentric coordinate linear interpolation

Laplacian Interpolation

Laplacian interpolation

- Minimize the Laplacian of the mesh
- Electrode data as boundary conditions
- FE solution of the discrete Laplacian operator

Evaluation Criteria

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Root Mean Squared Error

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(V_i^{in} - V_i^{m})^2}$$

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Interpolated Voltage Potential

Evaluation Criteria

Root Mean Squared Error

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(V_i^{in} - V_i^{m})^2}$$

Interpolated Voltage Potential

Measured Voltage Potential

Evaluation Criteria

Root Mean Squared Error

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(V_i^{in} - V_i^{m})^2}$$

Interpolated Voltage Potential (V_i^{in})

Measured Voltage Potential (V_i^{m})

Correlation Coefficient

$$CC = \frac{\sum_{i=1}^{n}(V_i^{in} - \bar{V}_i^{in})(V_i^{m} - \bar{V}_i^{m})}{\sqrt{\sum_{i=1}^{n}(V_i^{in} - \bar{V}_i^{in})^2}\sqrt{\sum_{i=1}^{n}(V_i^{m} - \bar{V}_i^{m})^2}}$$

Evaluation Criteria

Root Mean Squared Error

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(V_i^{in} - V_i^{m})^2}$$

Interpolated Voltage Potential

Measured Voltage Potential

Correlation Coefficient

$$CC = \frac{\sum_{i=1}^{n}(V_i^{in} - \bar{V}_i^{in})(V_i^{m} - \bar{V}_i^{m})}{\sqrt{\sum_{i=1}^{n}(V_i^{in} - \bar{V}_i^{in})^2}\sqrt{\sum_{i=1}^{n}(V_i^{m} - \bar{V}_i^{m})^2}}$$

Max Gradient Relative Error

$$MaxGradRE = MAX\left(\frac{\nabla V_i^{in} - \nabla V_i^{m}}{\nabla V_i^{m}}\right)$$

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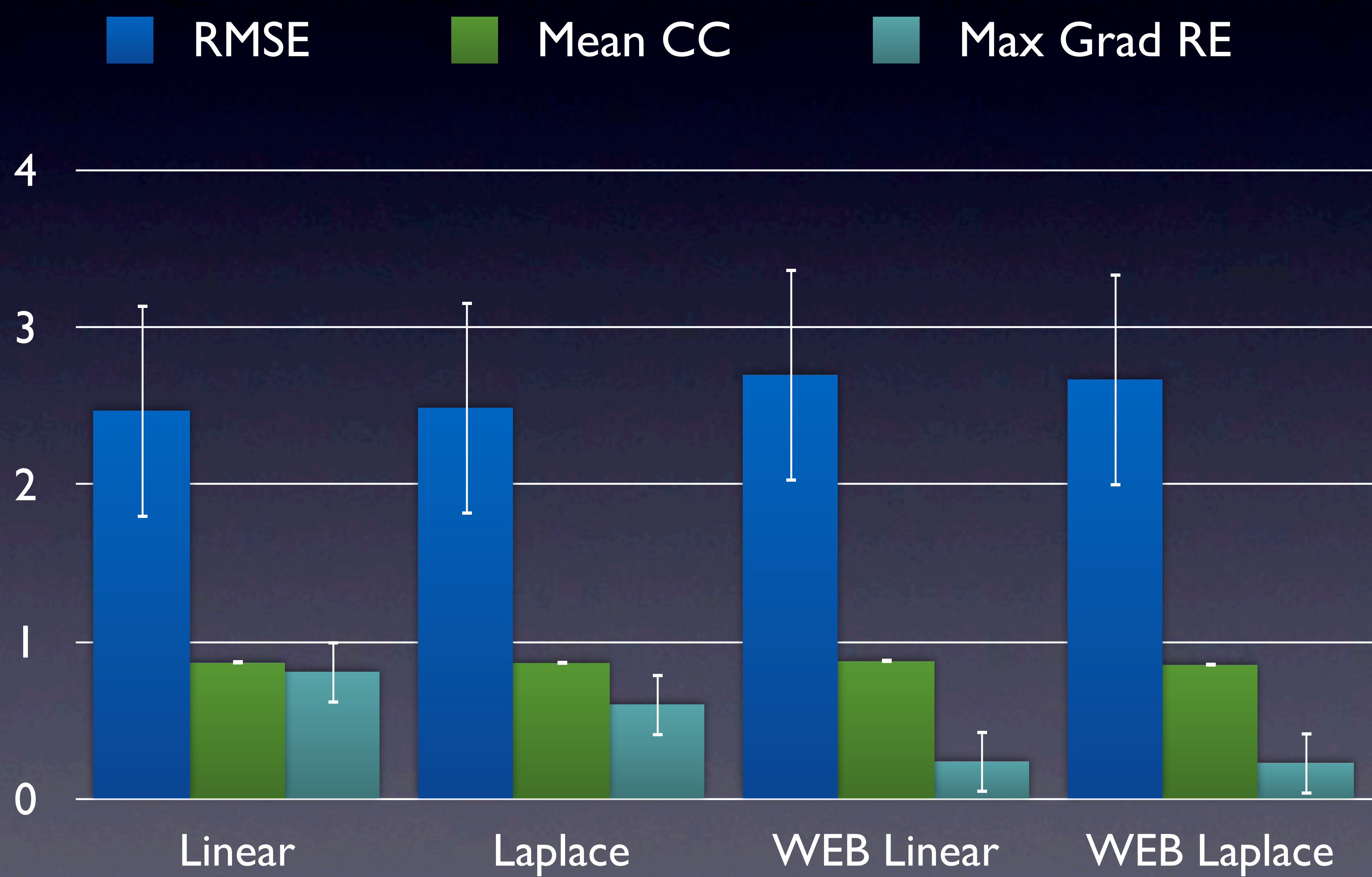
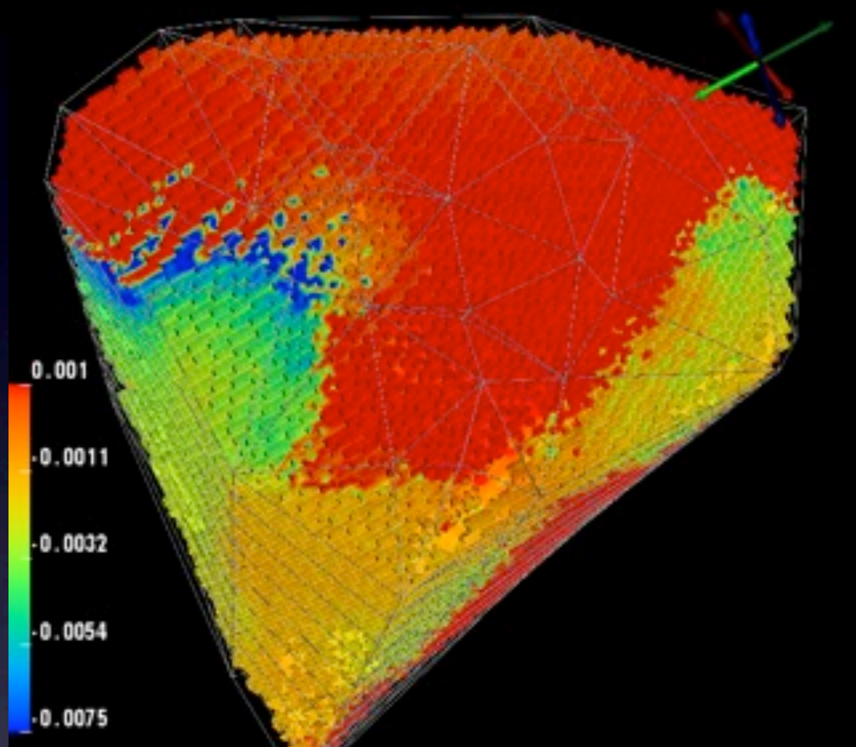
Results

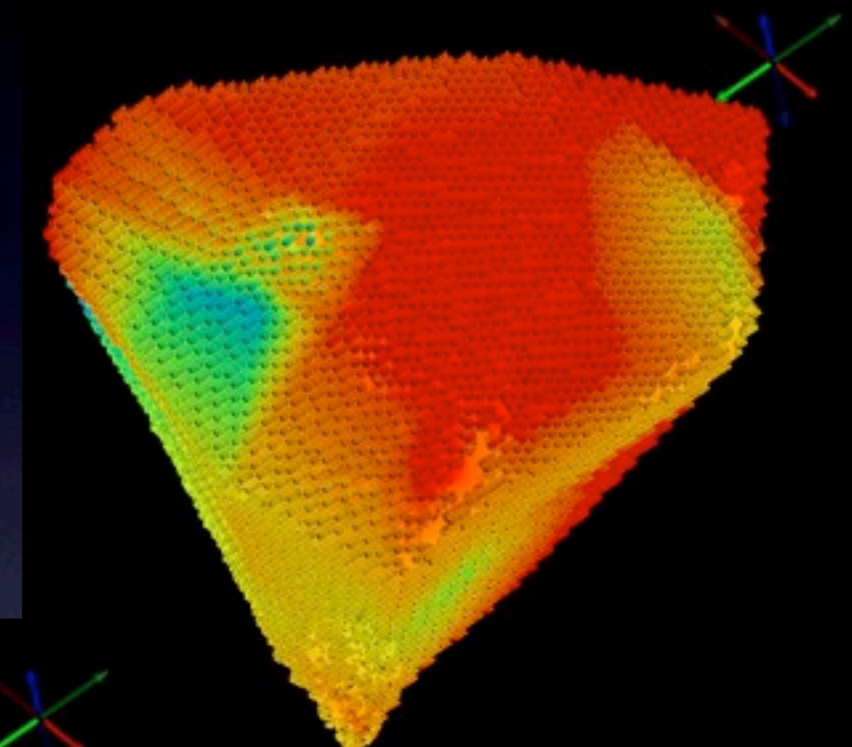

RMSE
Mean CC
Max Grad RE
4
3
2
1
0
Linear
Laplace
WEB Linear
WEB Laplace

Visual Inspection

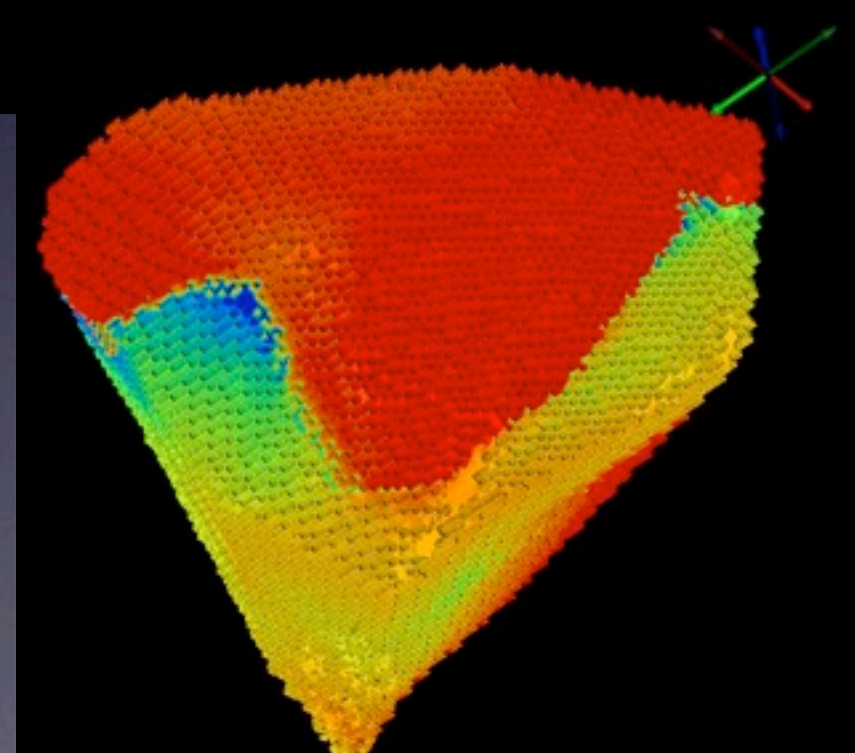
Gold Standard



Non-WEB Linear



WEB Linear



Discussion

WEB methods do not improve global statistics

- Preserves focal facet of the activation wave
- WEB assumptions not as accurate transmuraly as they are across the epicardium

Discussion

WEB methods preserve gradients

- More than 3 times more accurate gradients
- Wave front delineated better

Conclusion

What are we looking for

- Gradients
- Activation front
- Relative minimum and maximum potentials

Questions