Temporal Dilation of Animal Cardiac Recordings Registered to Human Torso Geometry

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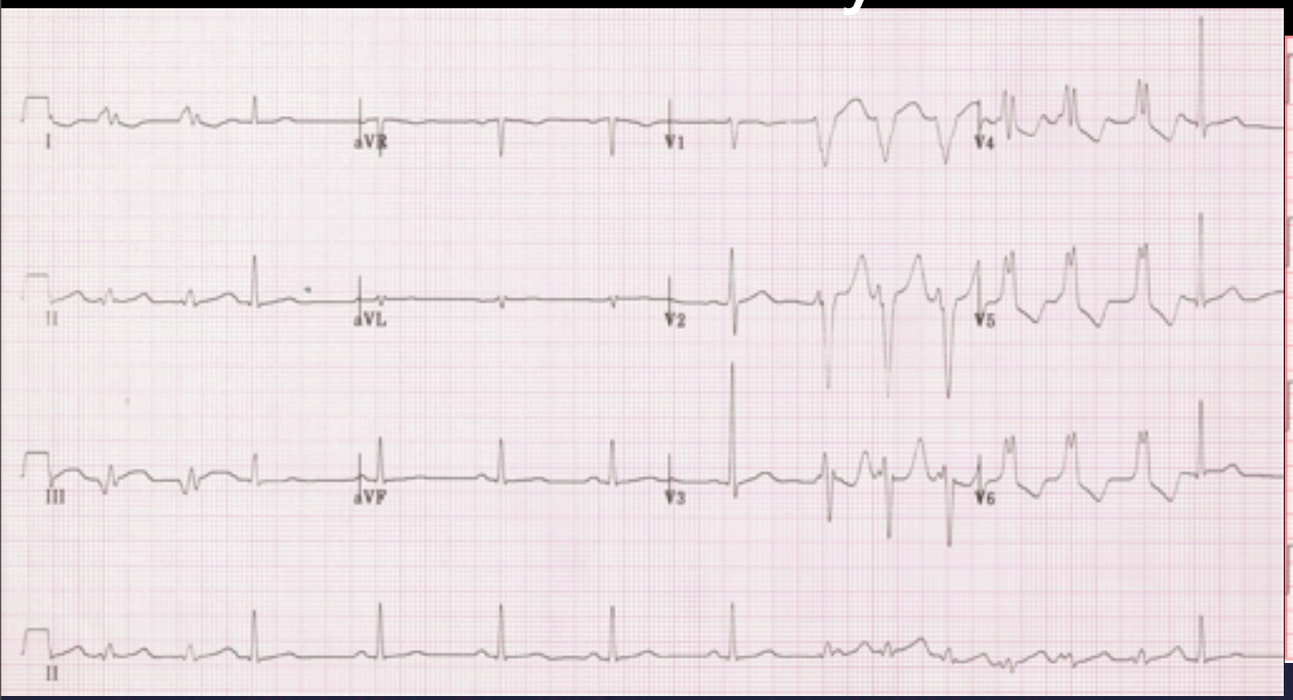
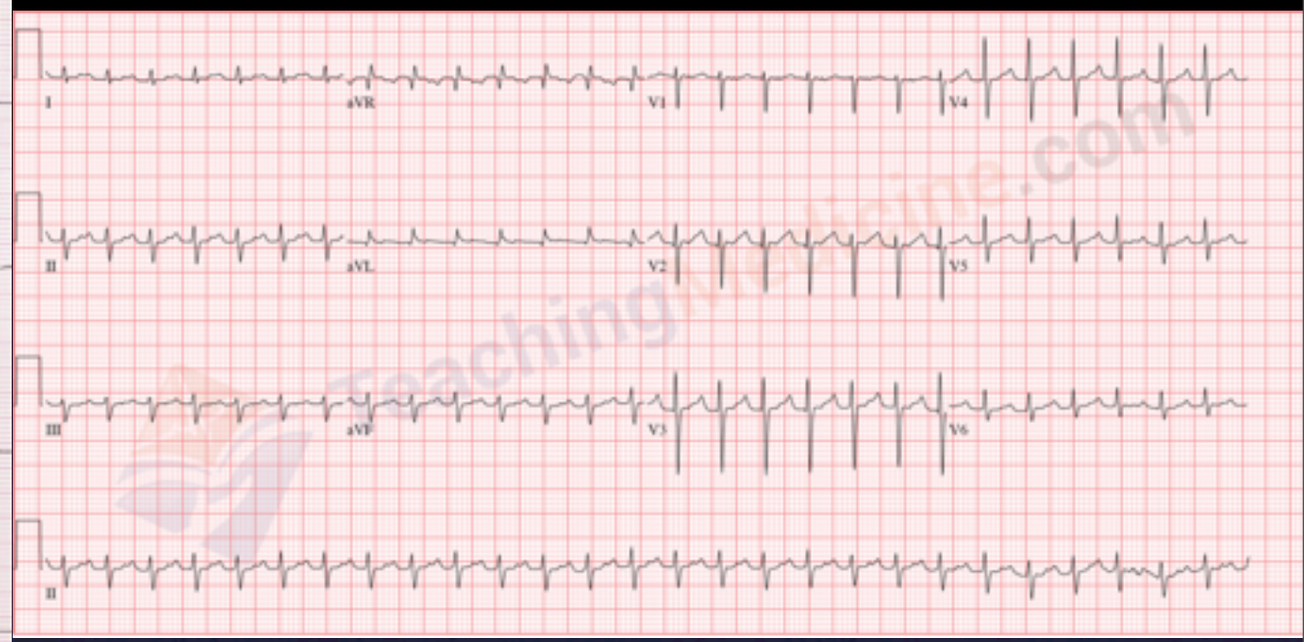
Arrhythmia Detection

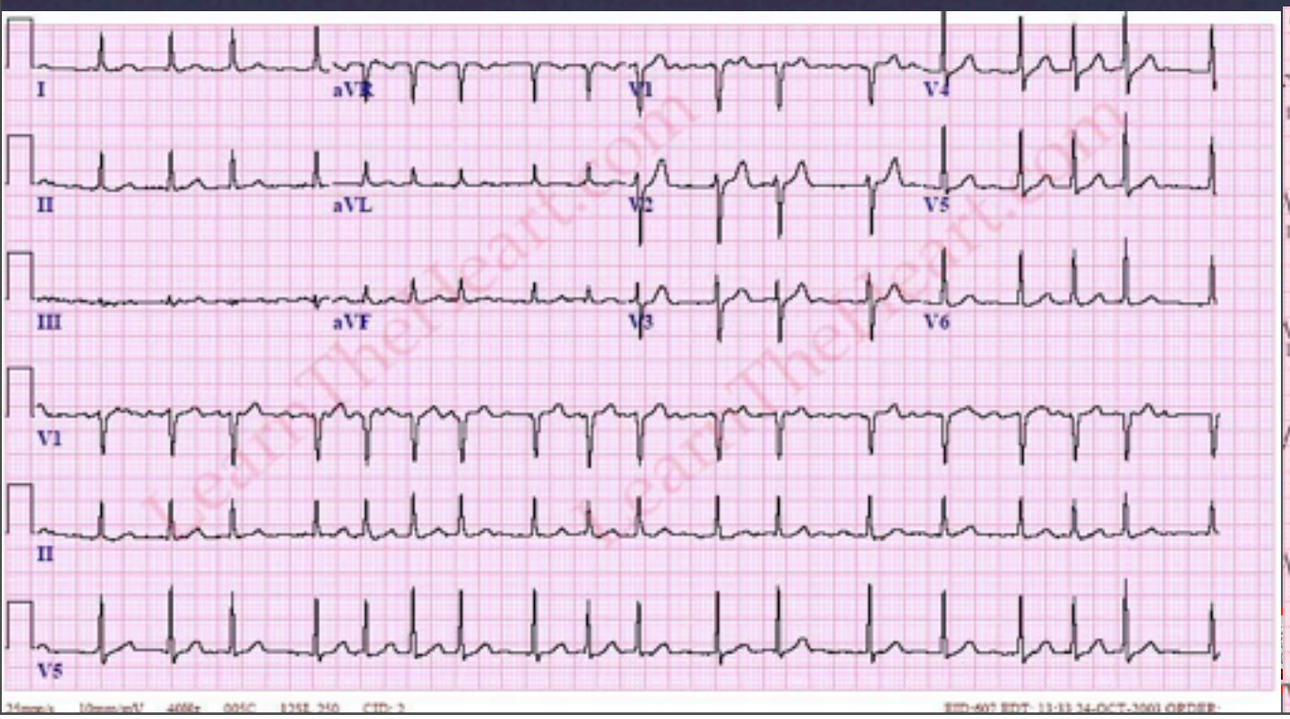
Ventricular Tachycardia



SupraVentricular Tachycardia



Atria Fibrillation

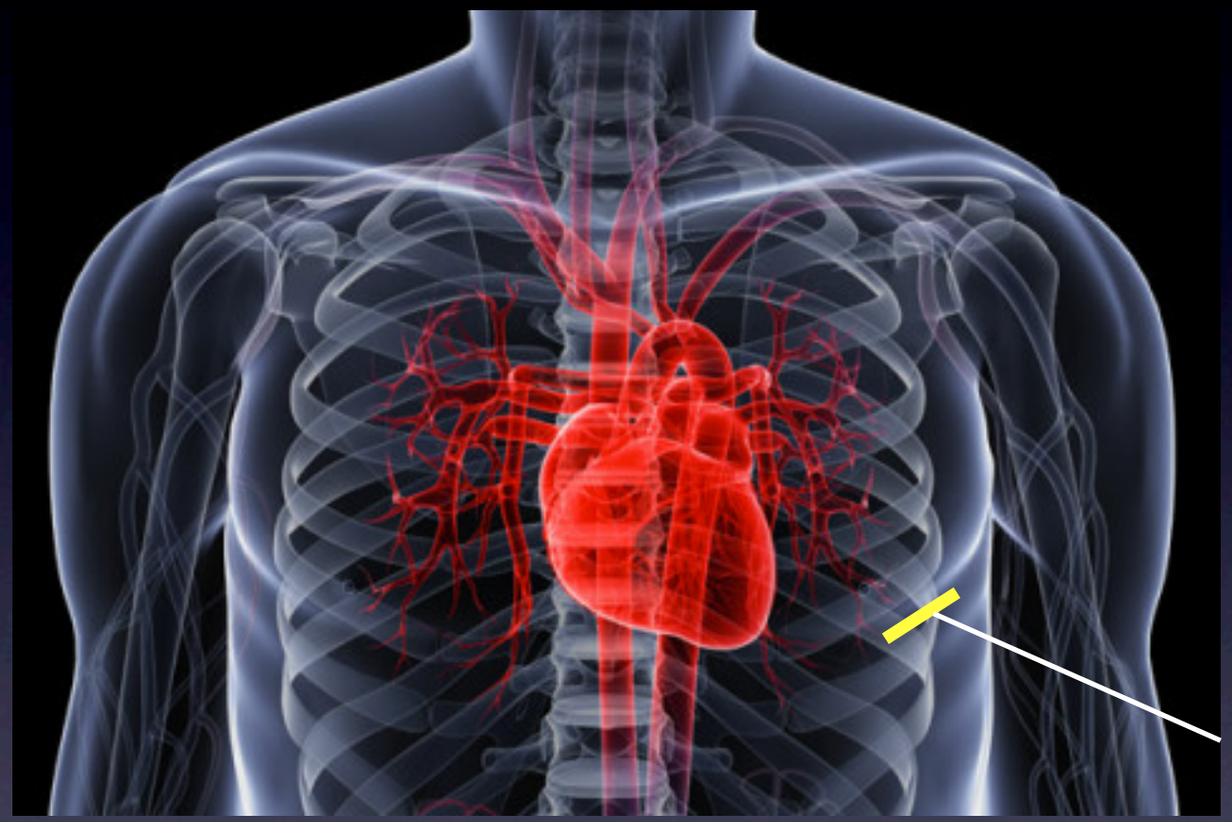


Ventricular Fibrillation

What do signals look like internally?

Clinical recordings can be difficult and expensive to obtain

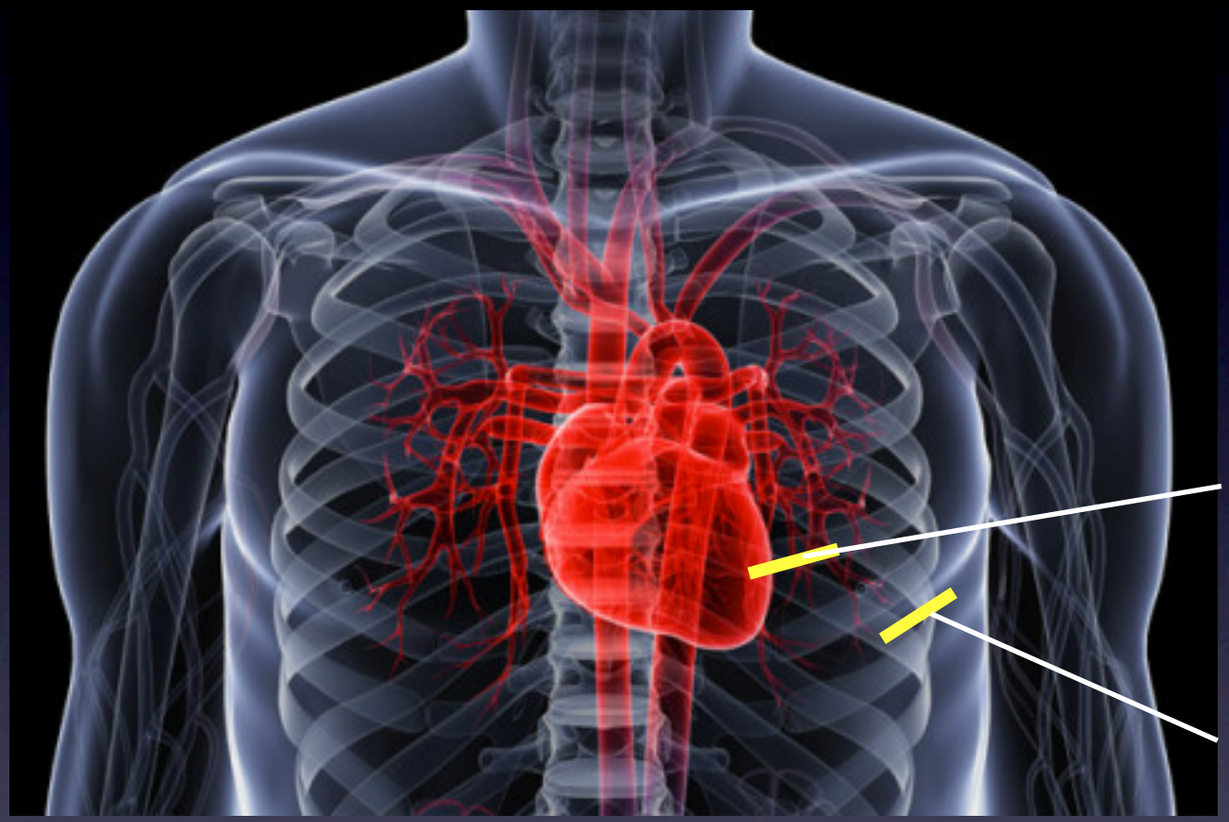
What do signals look like internally?



Subcutaneous?

Clinical recordings can be difficult and expensive to obtain

What do signals look like internally?



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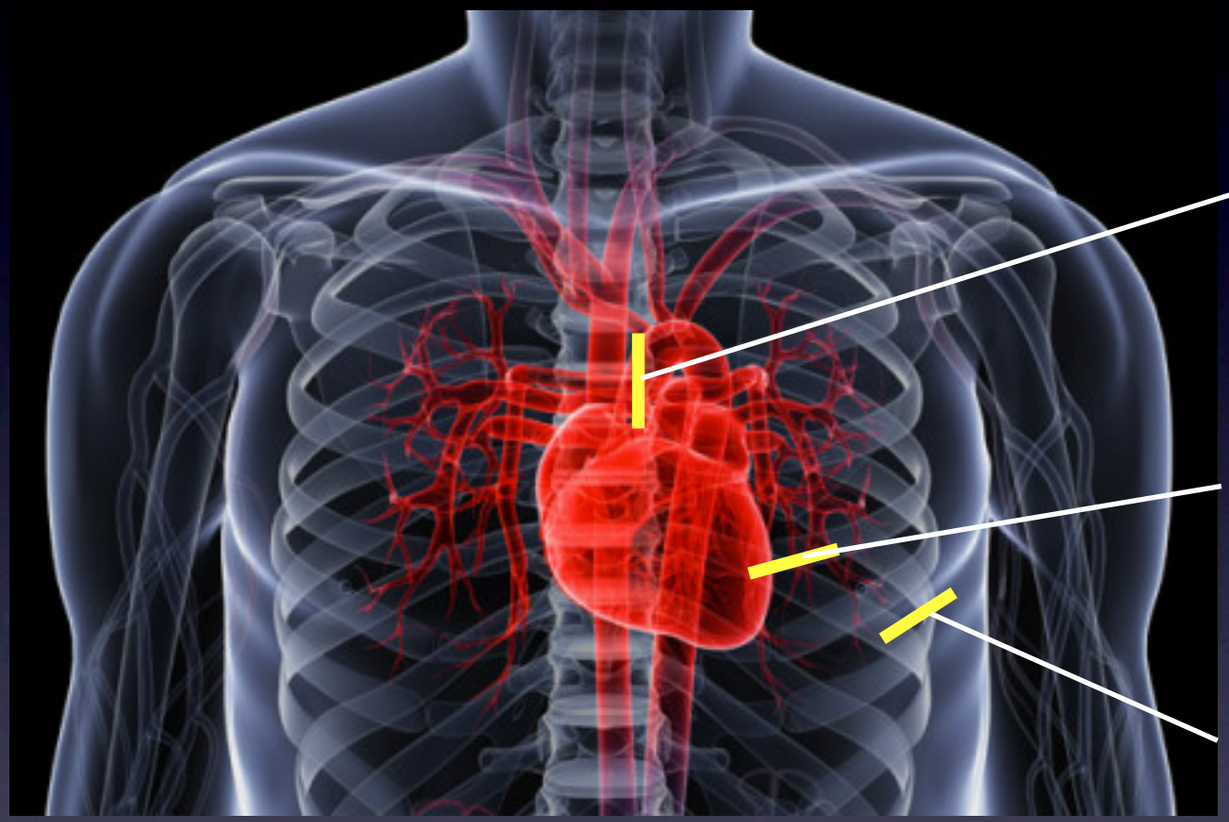
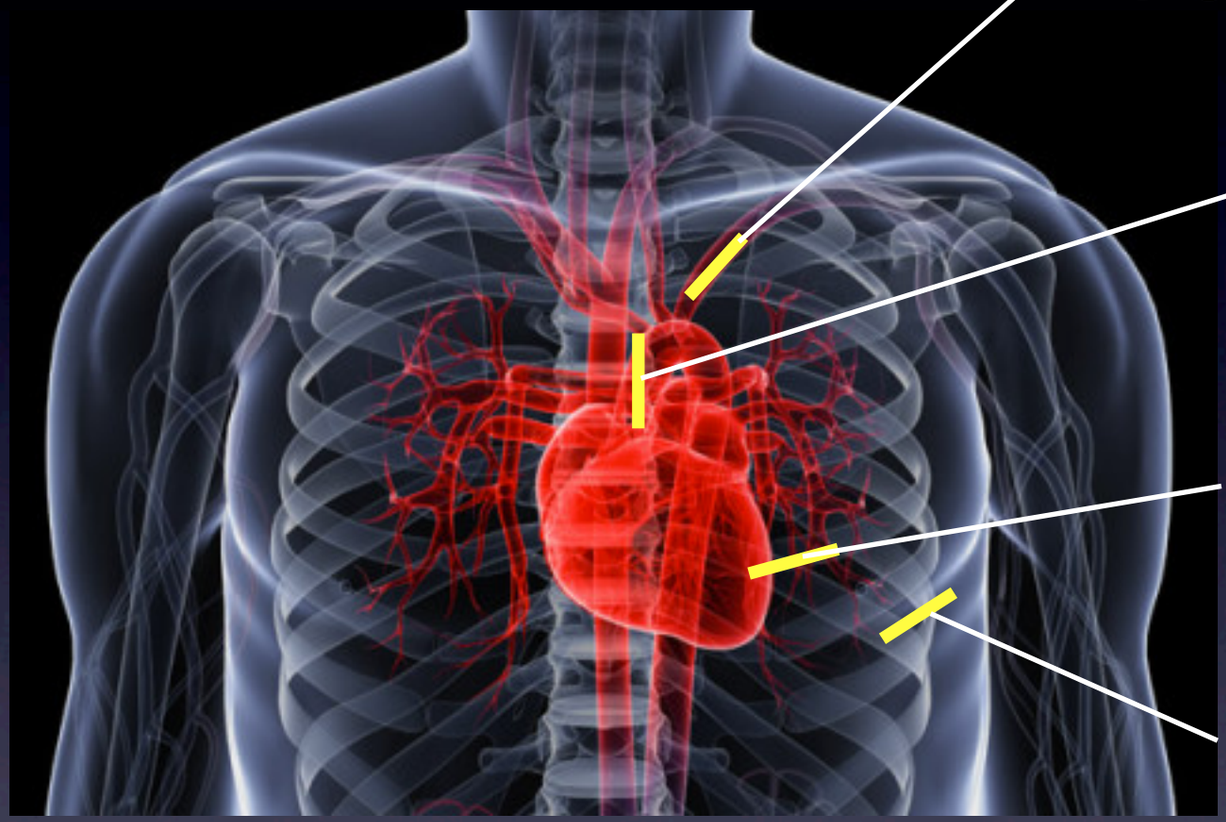
What do signals look like internally?



Clinical recordings can be difficult and expensive to obtain

What do signals look like internally?



IntraVenous/Arterial?

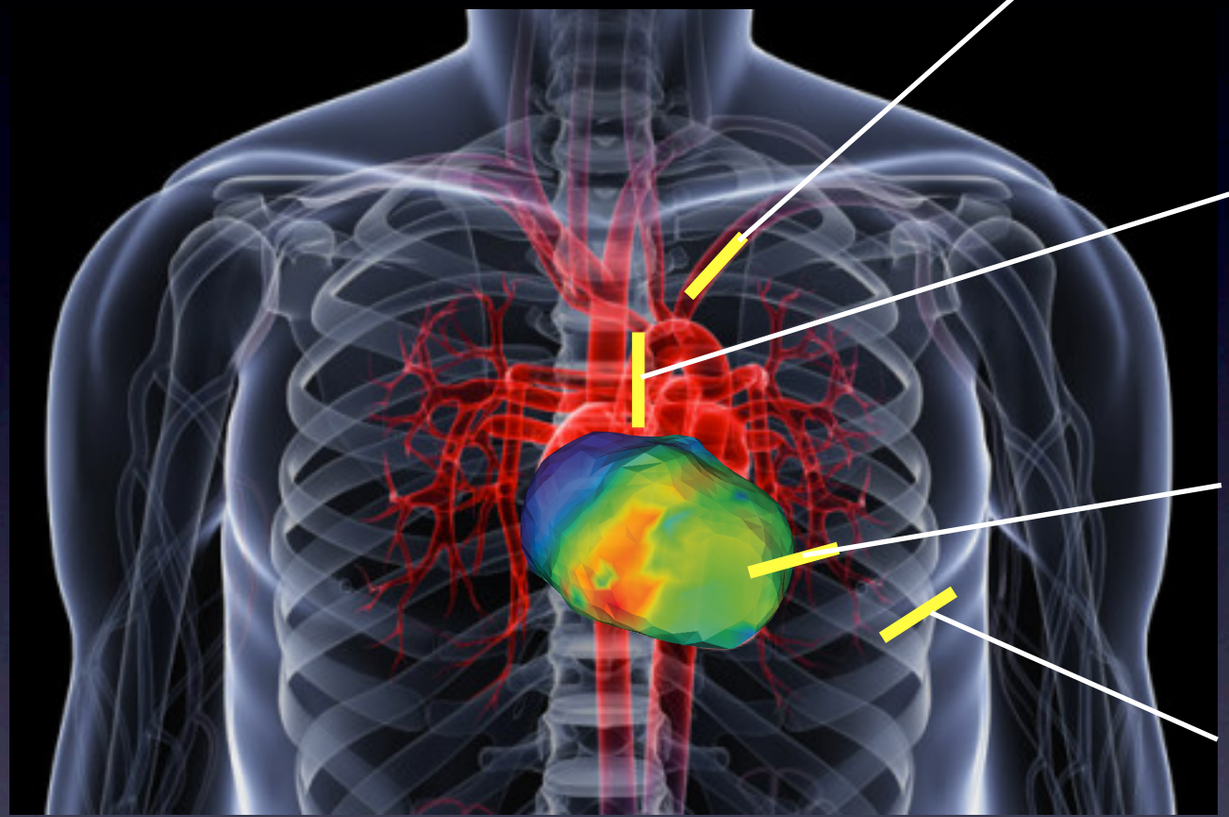
Esophageal?

Under Rib Cage?

Subcutaneous?

Clinical recordings can be
difficult and expensive to obtain

Simulate Potential Field



IntraVenous/Arterial

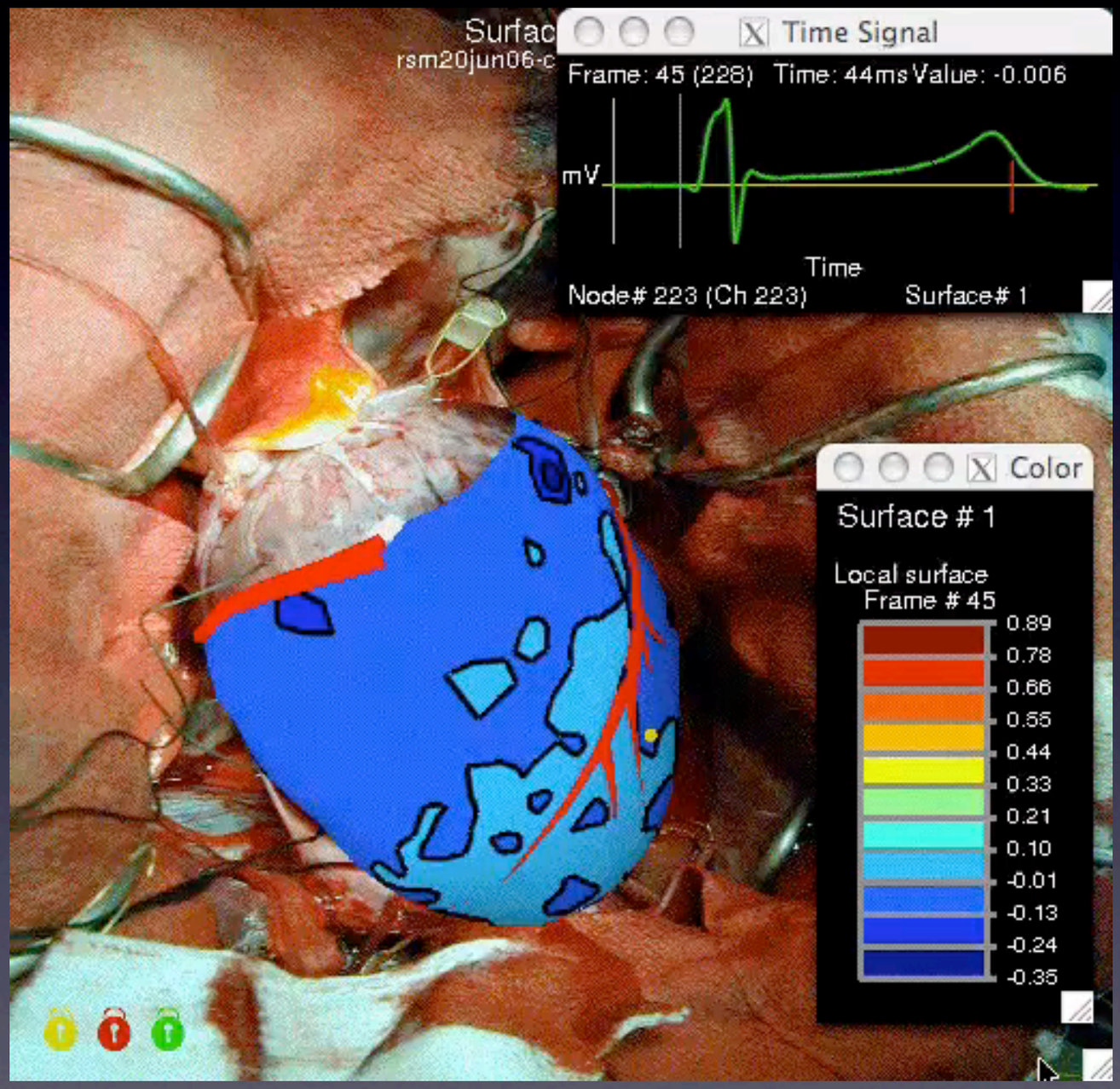
Esophageal

Under Rib Cage

Subcutaneous

Calculate ECG Forward Solutions using FEM

Source Potentials



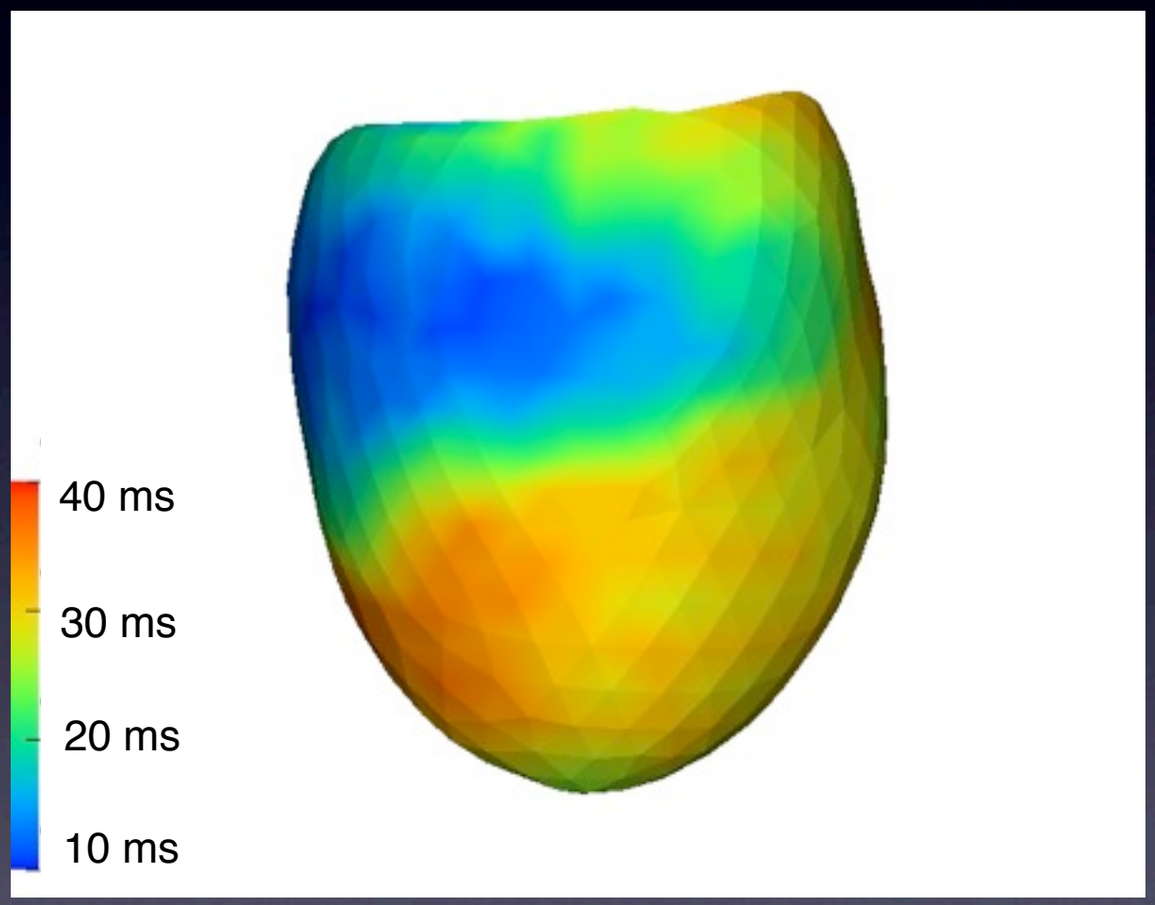
Decades of experiments

Cardiac surface recordings

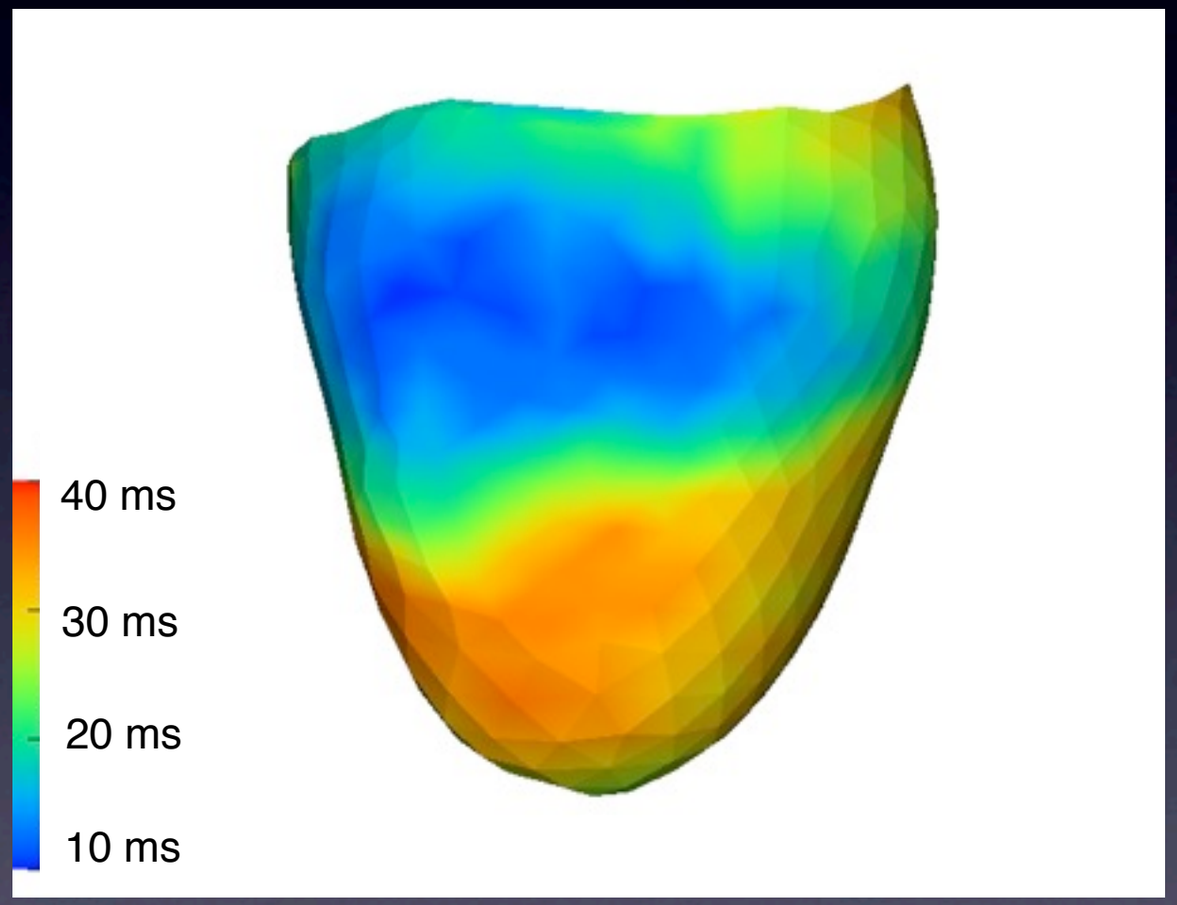
Dogs and Pigs

Temporal Error Due to Registration

Original animal geometry



Registered to human torso geometry



Change in size introduces artifacts

Temporal Error Due to Registration

Original animal geometry

4 mm

Registered to human torso geometry

9 mm

Δ activation times = 20 ms

CV = 19 cm/s

Δ activation times = 20 ms

CV = 45 cm/s

Temporal Error Due to Registration

Original animal geometry

4 mm

Registered to human torso geometry

9 mm

Δ activation times = 20 ms

Δ activation times = 20 ms

CV = 19 cm/s

CV = 45 cm/s

CV is not maintained.

Temporal Error Due to Registration

Original animal geometry

4 mm

Registered to human torso geometry

9 mm

Δ activation times = 20 ms

CV = 19 cm/s

Δ activation times = 47 ms

CV = 20 cm/s

Temporal Error Due to Registration

Original animal geometry

4 mm

Registered to human torso geometry

9 mm

Δ activation times = 20 ms

CV = 19 cm/s

Δ activation times = 47 ms

CV = 20 cm/s

Temporal Error Due to Registration

Original animal geometry

4 mm

Registered to human torso geometry

9 mm

Δ activation times = 20 ms

CV = 19 cm/s

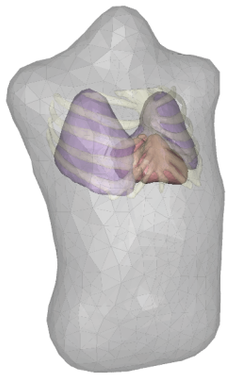
Δ activation times = 47 ms

CV = 20 cm/s

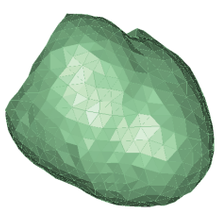
caps Pipeline

caps - Cardiac Arrhythmia Potential Simulation

Human Torso Geometries

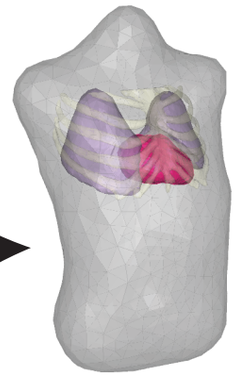


Animal Heart Geometries

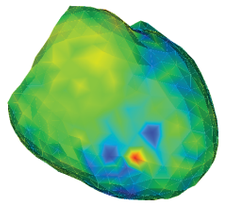


Geometric Registration

Registered Geometries



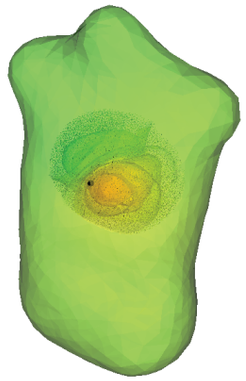
Recorded Animal Heart Potentials



Use Geometric Scaling

Temporal Dilation

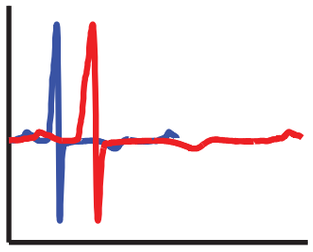
Simulated Torso Potentials



FEM Simulation

Forward Matrix

$$\begin{bmatrix} \text{Lead} \\ \text{Field} \\ \text{Matrix} \end{bmatrix} * \quad$$

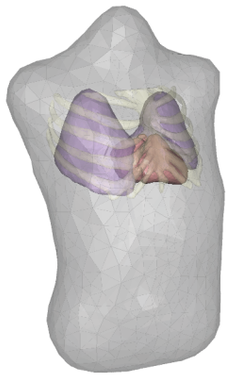


Dilated Heart Potentials

caps Pipeline

caps - Cardiac Arrhythmia Potential Simulation

Human Torso Geometries



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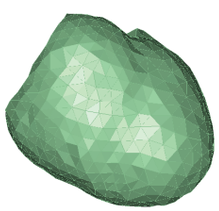

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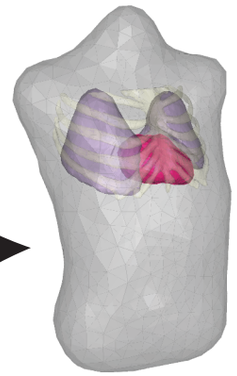
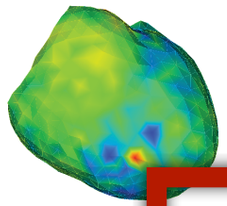


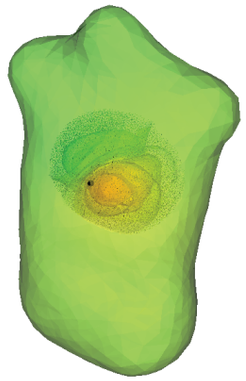
Recorded Animal Heart Potentials



Use Geometric Scaling

Temporal Dilation

Simulated Torso Potentials



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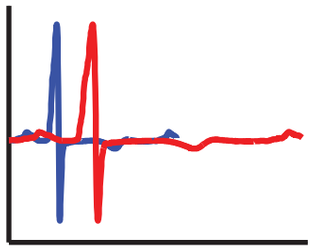
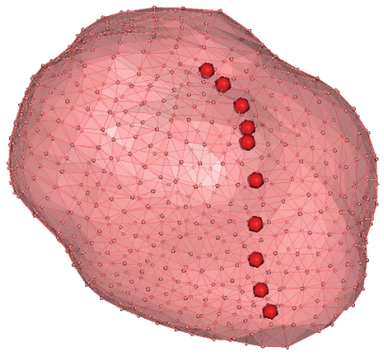


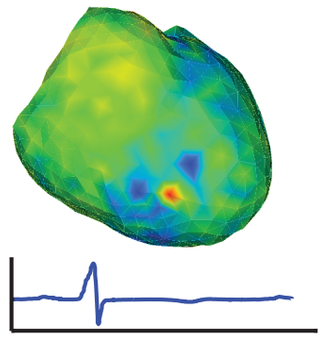
Dilated Heart Potentials

Temporal Dilation Pipeline

Registered Geometry

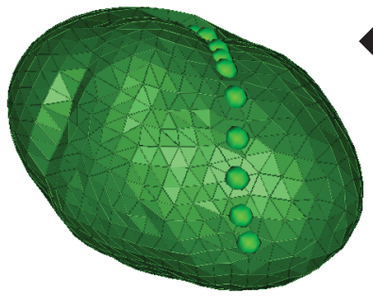


Recorded Animal Heart Potentials

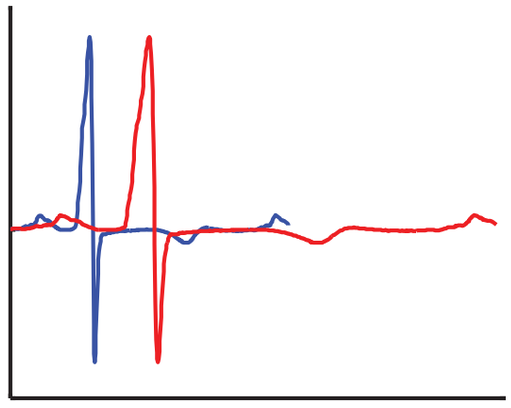


Change in Edge Length

Experimental Geometry



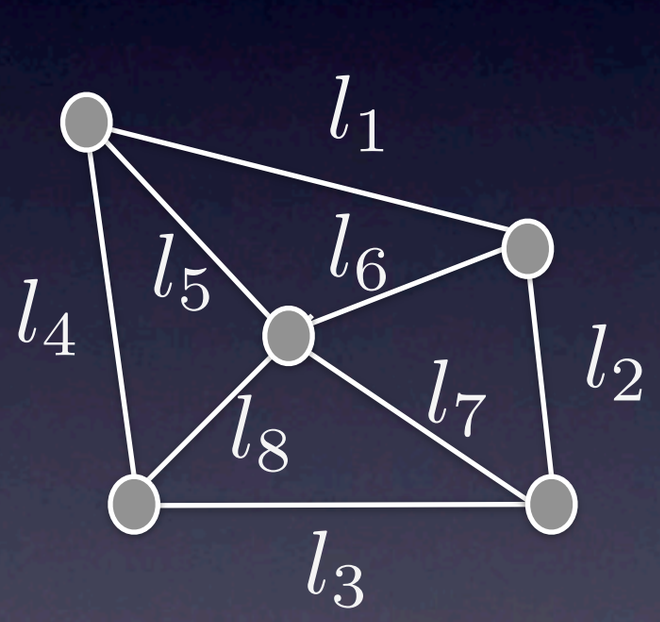
Time Corrected Heart Potentials

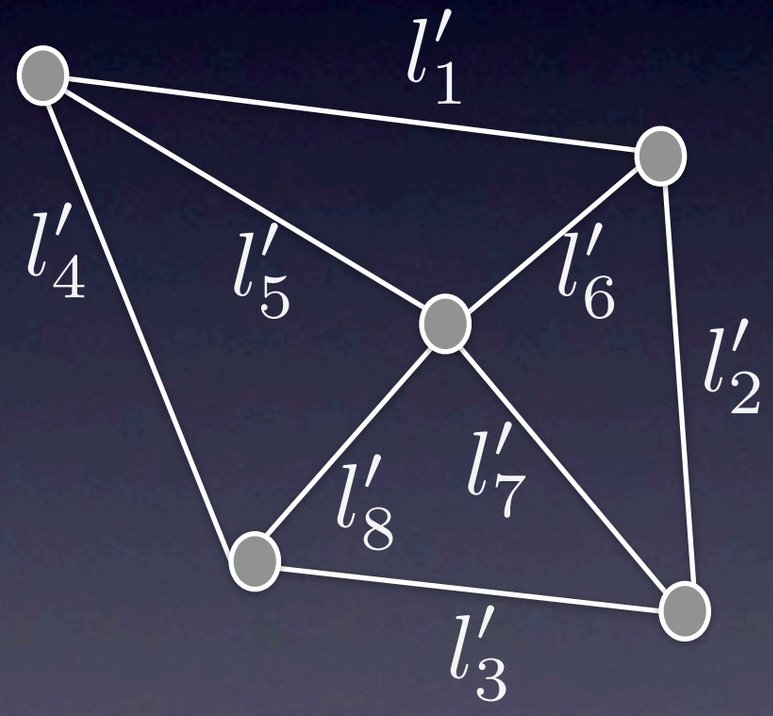


Global Scaling Factor

Original animal geometry

Registered to human torso geometry



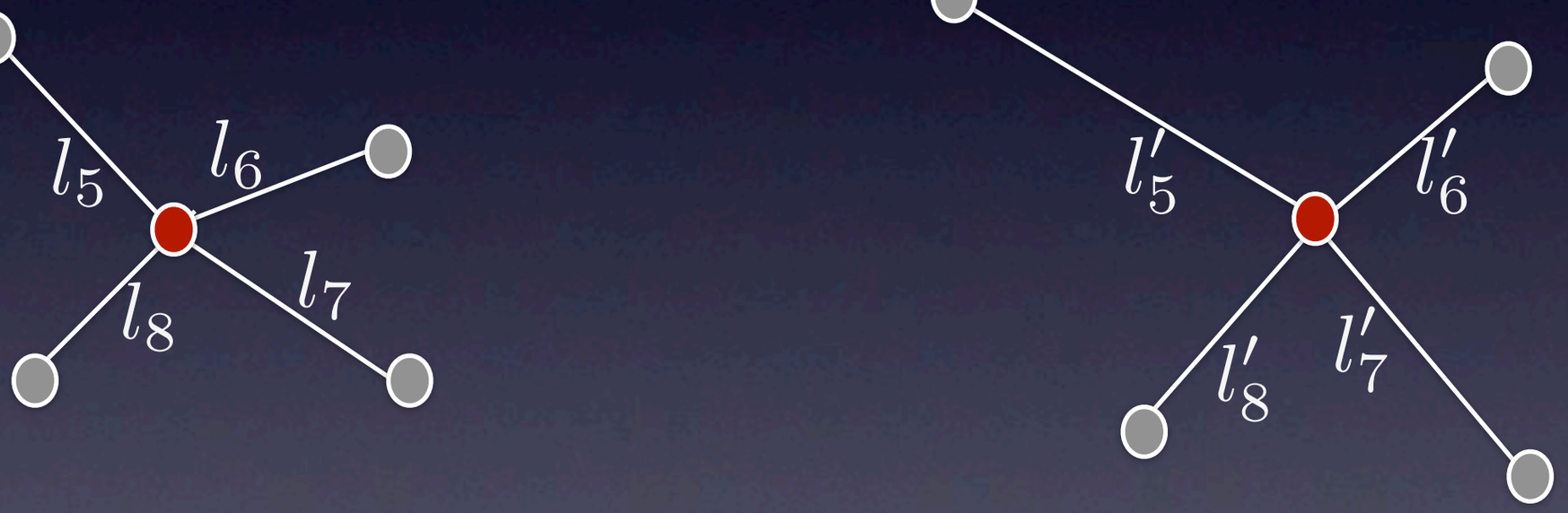


$$global = median\left(\frac{l_1}{l'_1}, \frac{l_2}{l'_2}, \frac{l_3}{l'_3}, \ldots\right)$$

Local Scaling Factors

Original animal geometry

Registered to human torso geometry



$$local(i=1) = median\left(\frac{l_5}{l'_5}, \frac{l_6}{l'_6}, \frac{l_7}{l'_7}, \frac{l_8}{l'_8}\right)$$

Local Scaling Factors

Original animal geometry

Registered to human torso geometry

$$local(i=2) = median\left(\frac{l_1}{l'_1}, \frac{l_4}{l'_4}, \frac{l_5}{l'_5}\right)$$

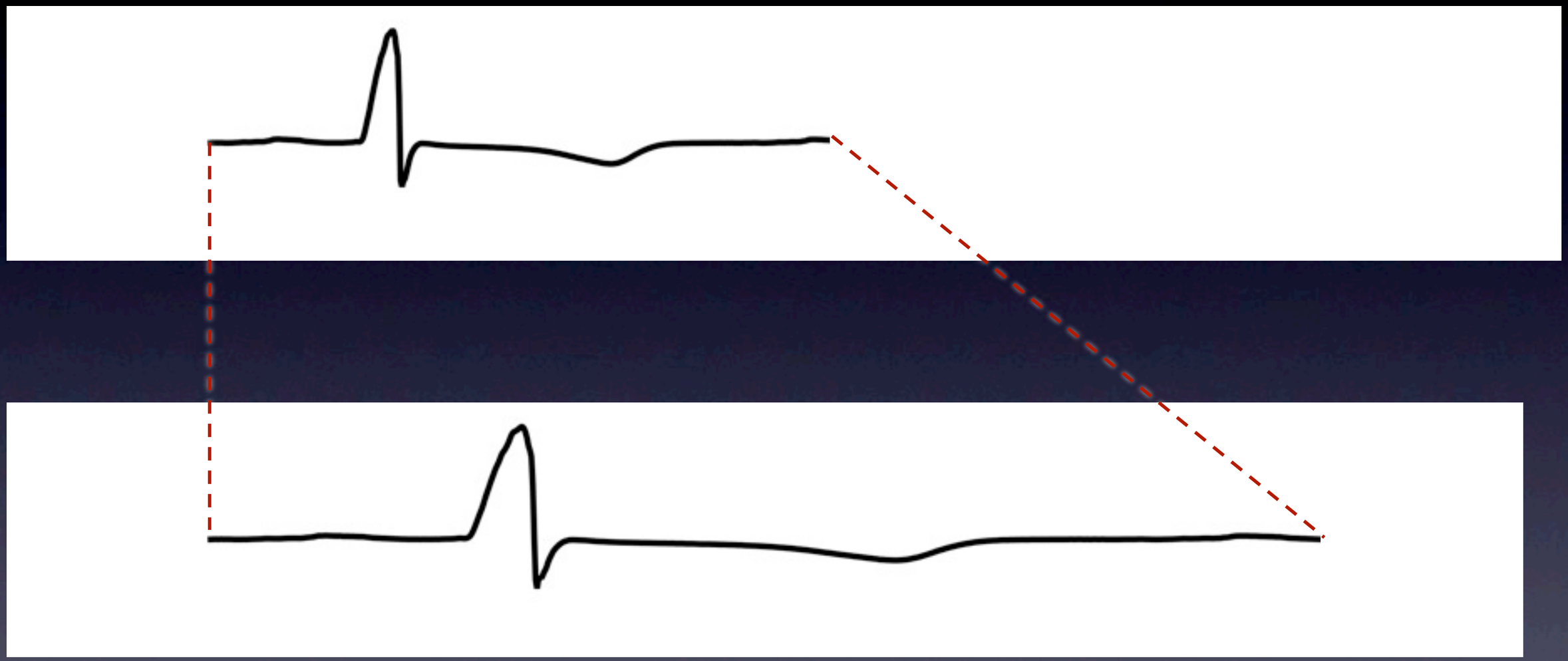
Local Scaling Factors

Original animal geometry

Registered to human torso geometry

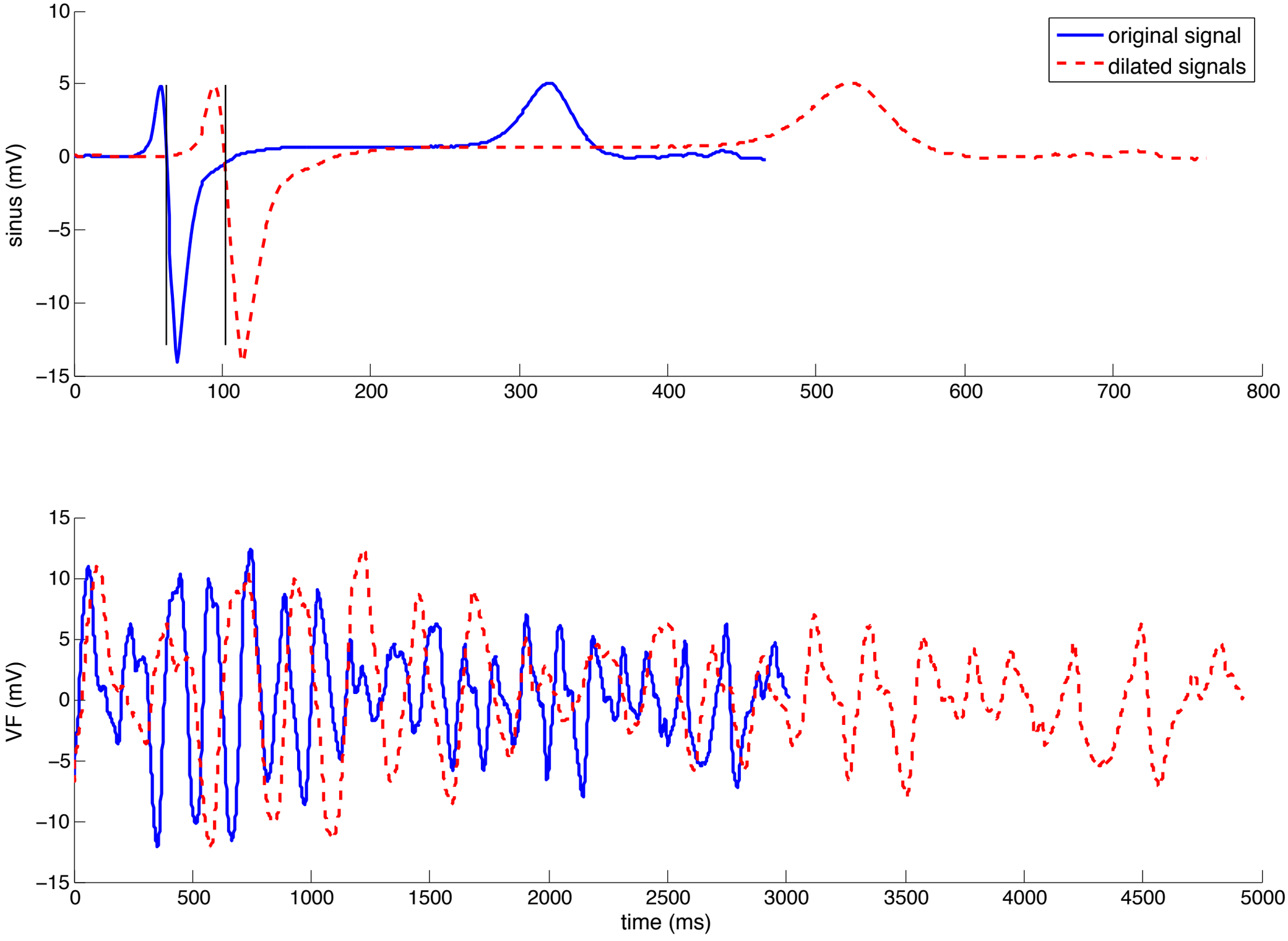
$$local(i) = \left[median \left(\sum_j \frac{neigh_i(j)}{neigh'_i(j)} \right) \right]$$

Linear Dilation



Regular Resampling

Dilated Cardiac Signals



Compare Conduction Velocity

Reported physiological values for CV

Canine (Original)	Canine	Human
33 ± 3 cm/s	21 to 53 cm/s	30 to 100 cm/s

Mean CV after temporal dilation

Torso	Global	Local
1	34 ± 3 cm/s	17 ± 3 cm/s
2	35 ± 3 cm/s	19 ± 3 cm/s

Roberts, et al. *Circulation Research* 1979, Katz *Physiology of the Heart* 2010

Compare Total Activation Time

Reported physiological values for TAT

Canine (Original)	Canine	Human
34 ± 4 ms	20 to 30 ms	30 to 50 ms

Mean TAT after temporal dilation

Torso	Global	Local
1	58 ± 7 ms	266 ± 42 ms
2	54 ± 6 ms	192 ± 24 ms

Hill, Moore *Circulation* 1967, Cassidy, et. al *Circulation* 1984

Compare Activation Recovery Interval

Reported physiological values for ARI (ms)

Canine (Original)	Canine	Human
165 ± 13 ms	~120 to 220 ms	~170 to 350 ms

Mean ARI (ms) after temporal dilation

Torso	Global	Local
1	270 ± 26 ms	271 ± 24 ms
2	251 ± 1 ms	237 ± 23 ms

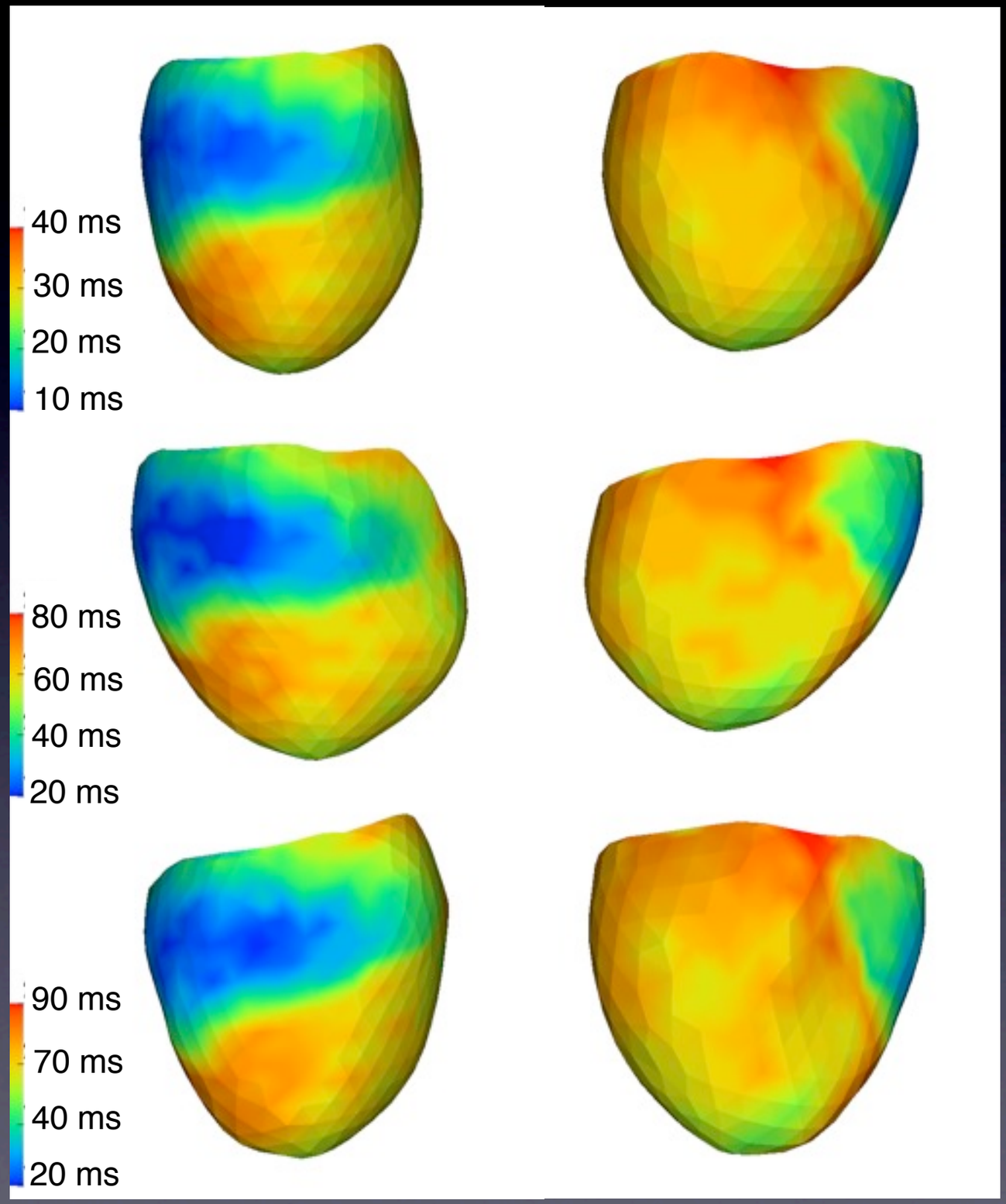
Haws, Lux *Circulation* 1990, Yue, et. al *Circulation* 2004

Global Scaling Activation Times

Original

Torso 1

Torso 2

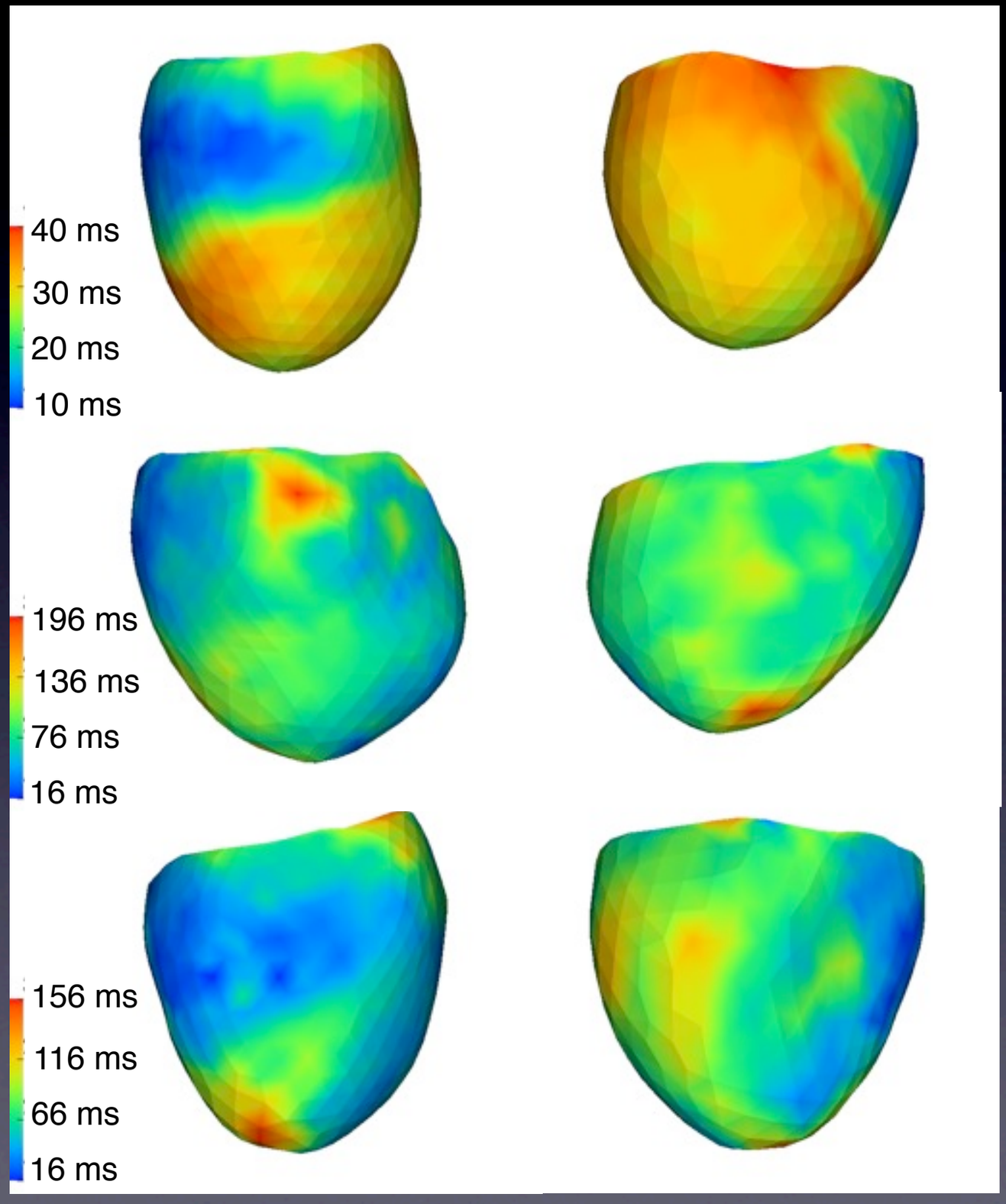


Local Scaling Activation Times

Original

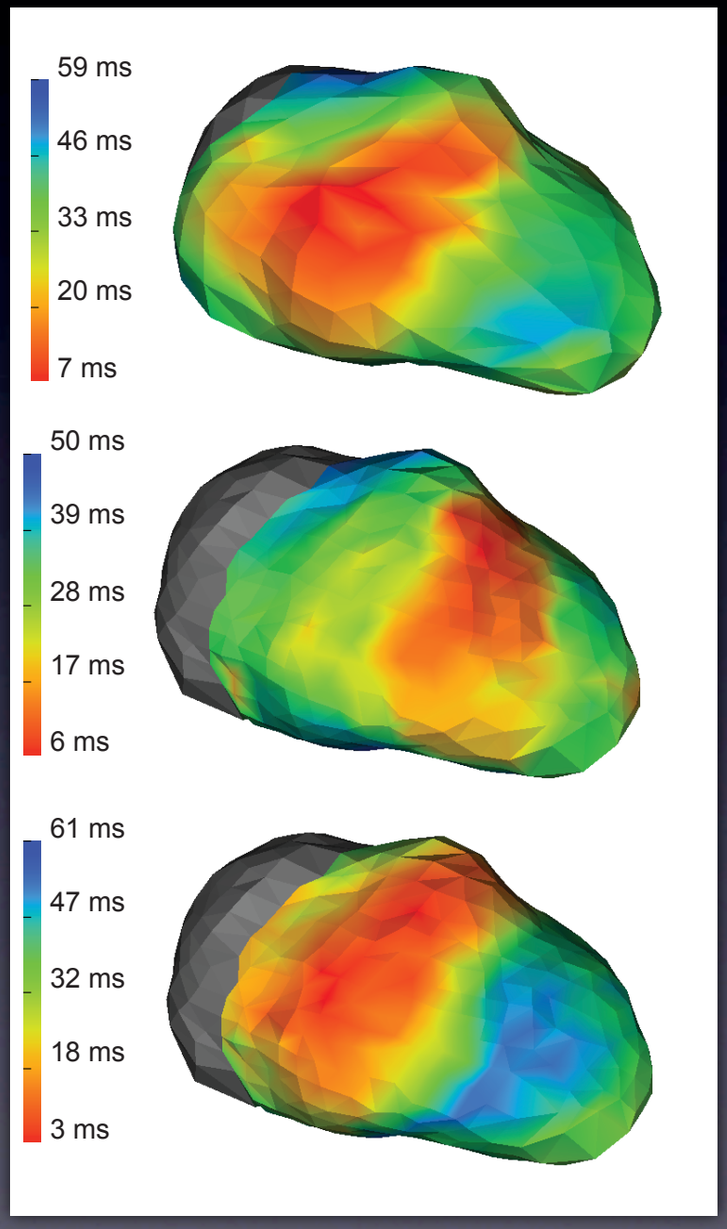
Torso 1

Torso 2

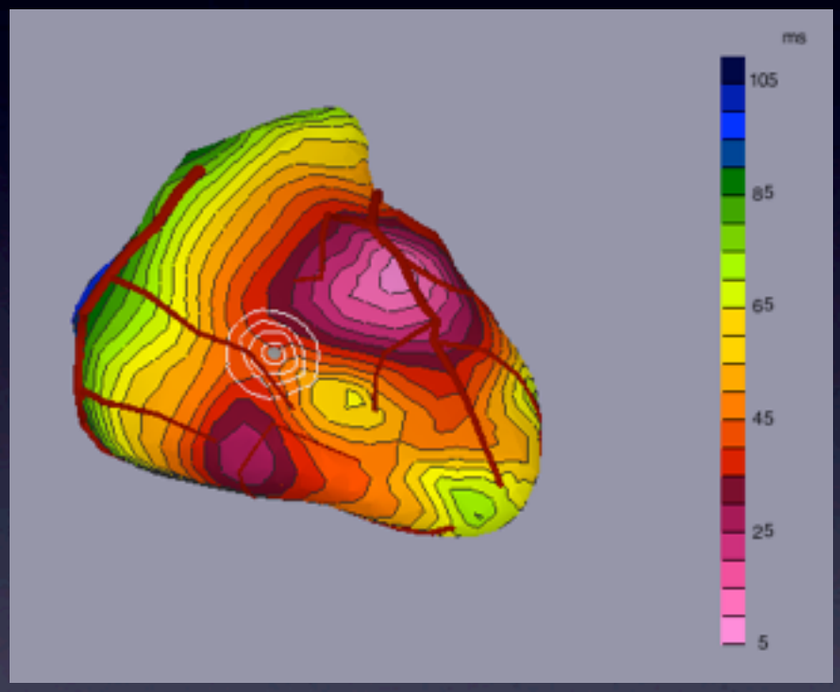


Activation Comparison

Dog Data Mapped to Human Geometry

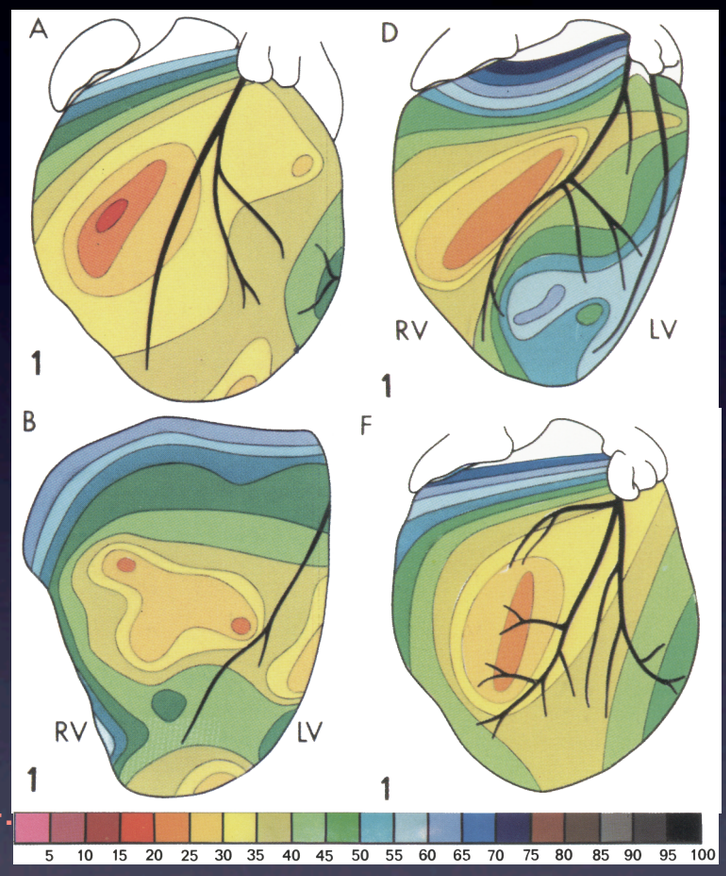


ECGSim



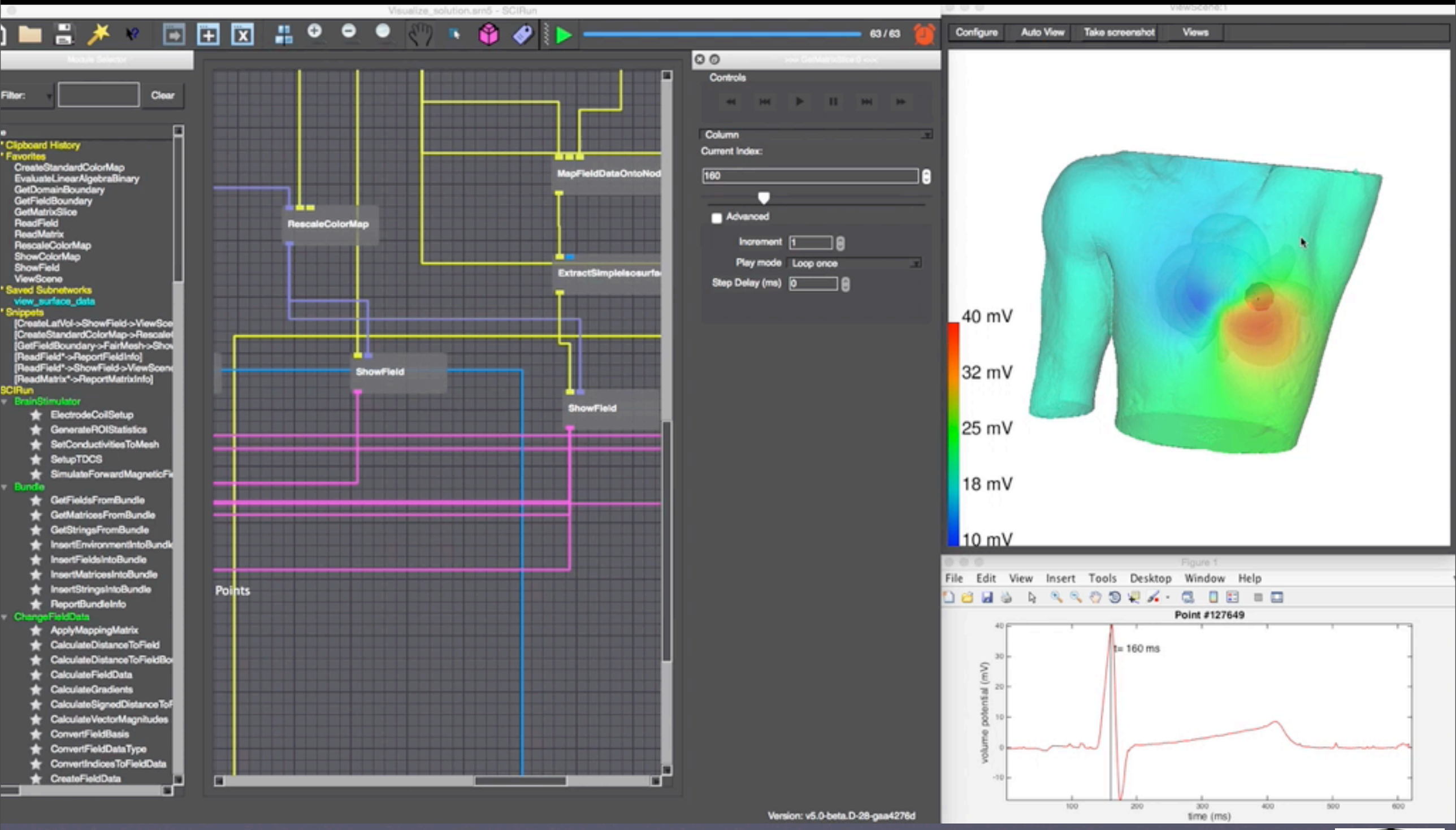
P. van Dam, et al. Comp. in Cardiology, 2014.

Durer, et al., Circ 1970



D. Durrer, et al. Circ. vol. 41 899-912, 1970

caps Interactive Exploration



Acknowledgements

Advisor

Rob MacLeod

Lab Members

Wilson Good
Kedar Aras
Brett Burton
Liz Jurrus

Medtronic Collaborators

Narendra Simha
Jeff Wilkinson
Josh Blauer
Darrell Swenson

CVRTI

Jayne Davis
Alicia Blooth
Phil Ershler
Bruce Steadman
Nancy Allen
Bonnie Punske

North Eastern University

Dana Brooks
Jaume Coll-Font

Support

Medtronic Inc.
Nora Eccles Treadwell Foundation
NIH P41GM103545