

The time is right: ECG Inverse solutions in research and clinical practice

Rob MacLeod, PhD

SCI Institute, Dept. of Bioengineering
CVRTI, CARMA

Consortium for ECG Imaging

University of Utah



The CEI Team

Dana Brooks



Linwei Wang



Peter v Dam



Olaf Dössel



Jaume Coll-Font



Jess Tate



Kedar Aras



Wilson Good



Walther Schulze

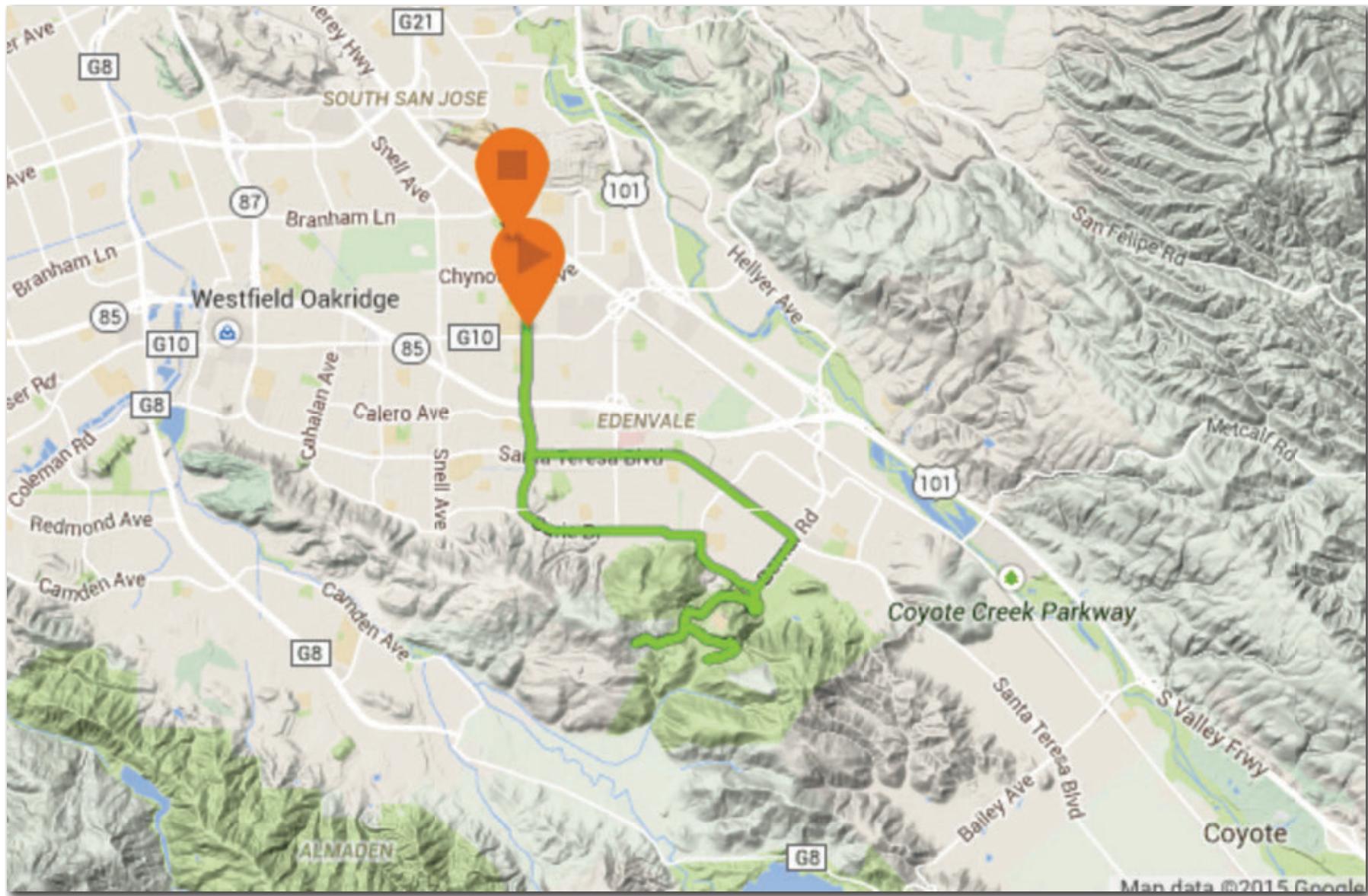


Danila Potyagaylo

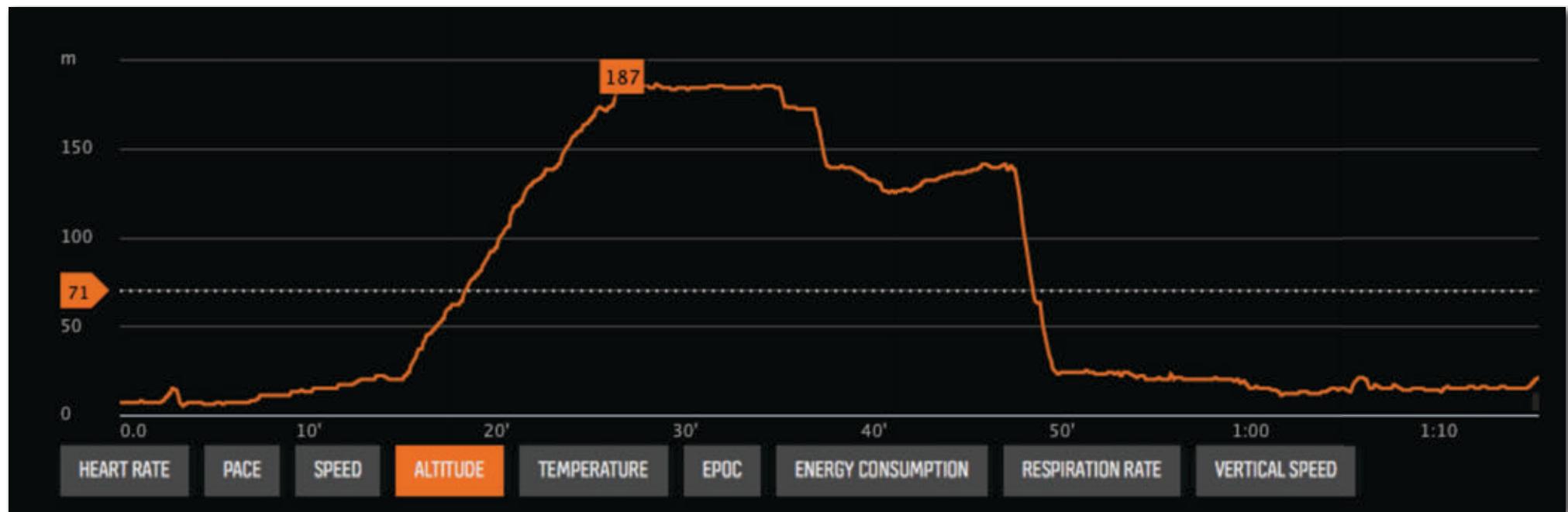
The Bike is Here



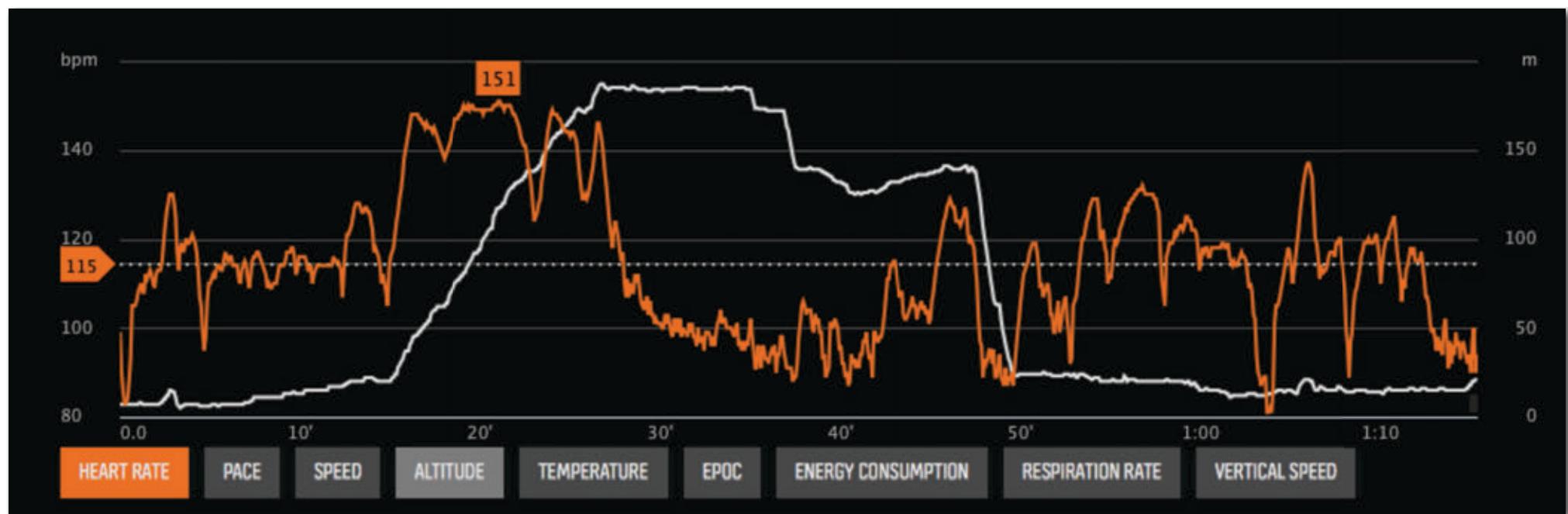
And Generating Data



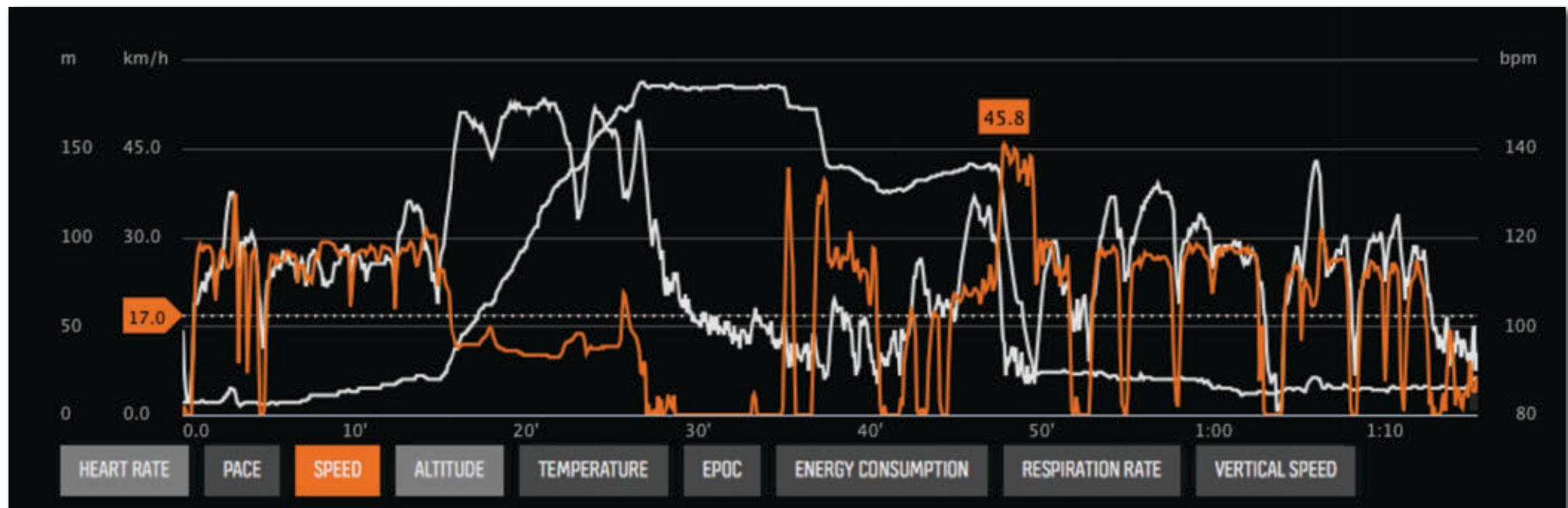
And Generating Data



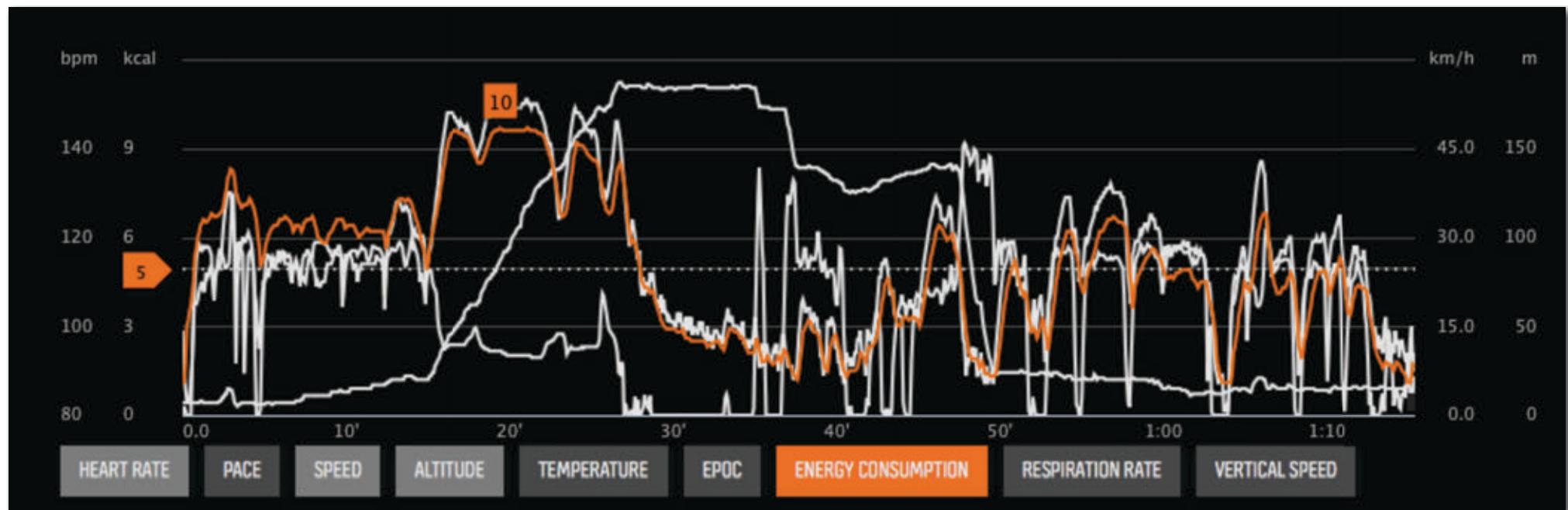
And Generating Data



And Generating Data



And Generating Data



And Generating Data

HEART RATE (80-151)	DISTANCE	SPEED (max 47.2)	RECOVERY TIME
114 bpm	21.38 km	17.0 km/h	3 h
PTE	CALORIES	ASCENT	DESCENT
1.8	373 kcal	218 m	203 m
ASCENT TIME	DESCENT TIME	FLAT TIME	HIGHEST POINT
0:33'50	0:20'20	0:21'12.7	187 m
LOWEST POINT	TEMPERATURE (25.4-30.2)	VO2	EASY
5 m	27.7 °C	18 ml/kg/min	1:01'19
MODERATE	HARD	EPOC PEAK	
0:13'55	0:00'09	13 ml/kg	

Can we Compare Data?



San Jose



Salt Lake
City

One Challenge Has Not Gone Away: Evaluation



Evaluation is Essential



It is Complicated



...and then, things got complicated.

And When in Doubt, it Should be Clinical



Validation approaches for electrocardiographic inverse problems

R. S. MacLeod

*Nora Eccles Harrison Cardiovascular Research and Training Institute (CVRTI),
University of Utah, Salt Lake City, Utah*

Email: macleod@cvrti.utah.edu

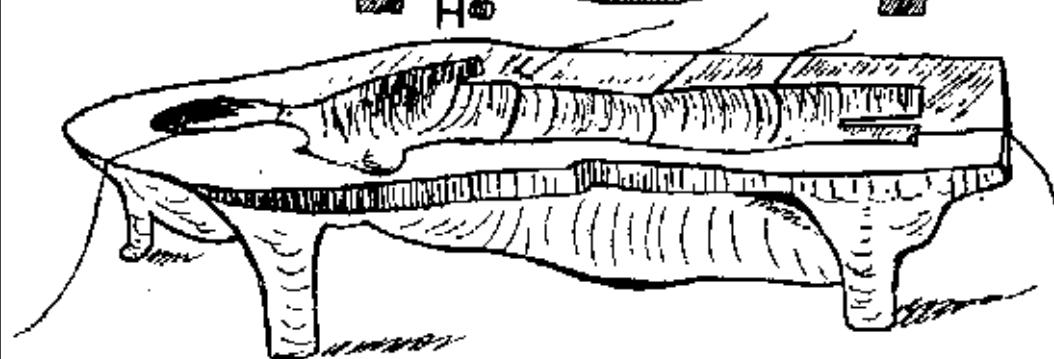
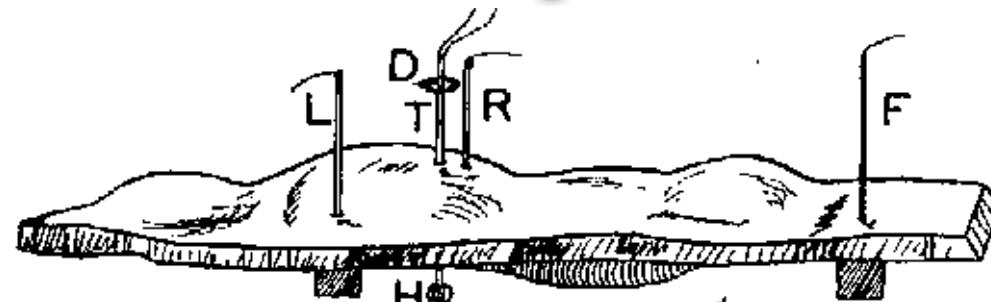
and D. H. Brooks

*Communications and Digital Signal Processing (CDSP) Center,
Electrical and Computer Engineering Department,
Northeastern University, Boston, Massachusetts*

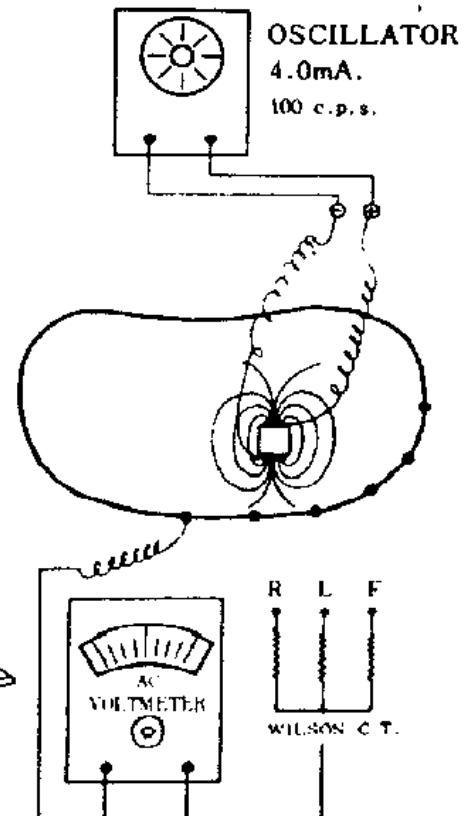
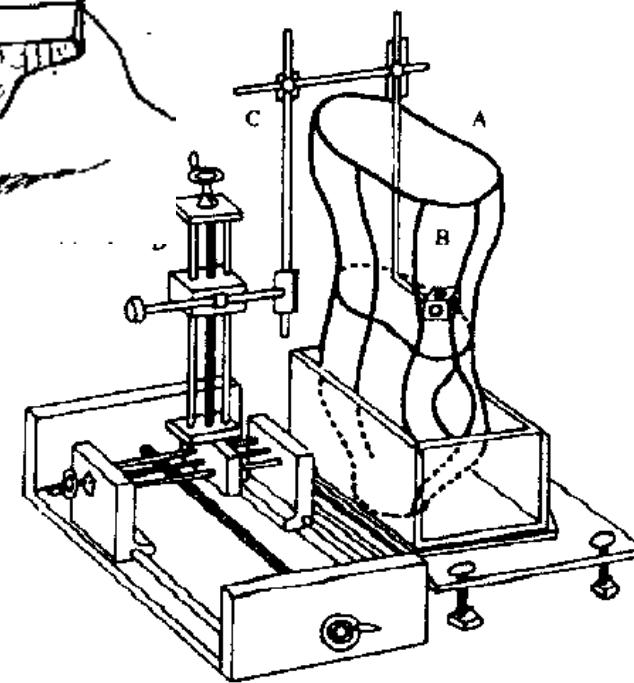
Email: brooks@cdsp.neu.edu

R.S. MacLeod and D.H. Brooks. Validation Approaches for Electrocardiographic Inverse Problems. In Computational Inverse Problems in Electrocardiography, Peter Johnston ed., 2000.

Physical Phantoms

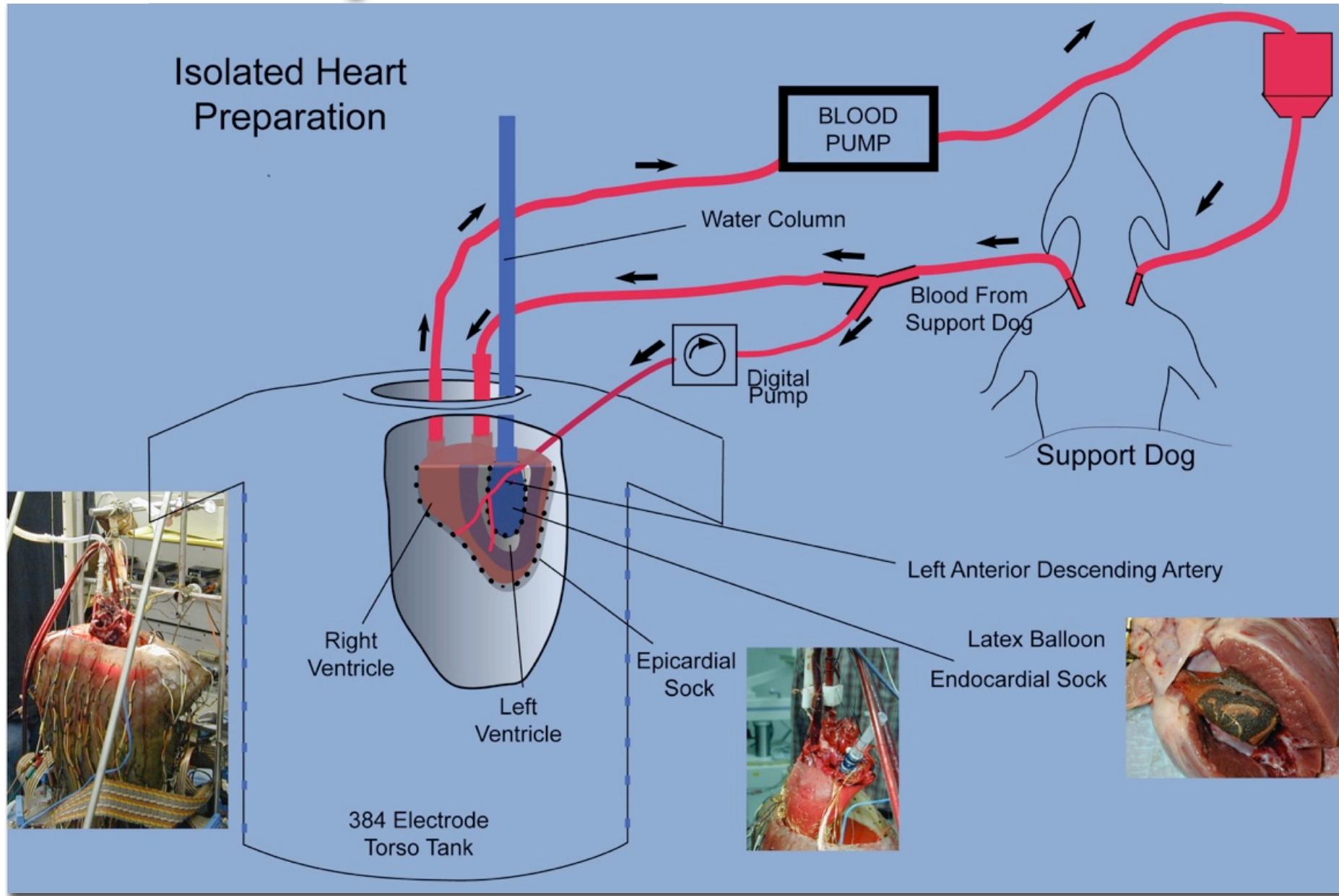


Burger and Van Milan, British Heart Journal,
1948.

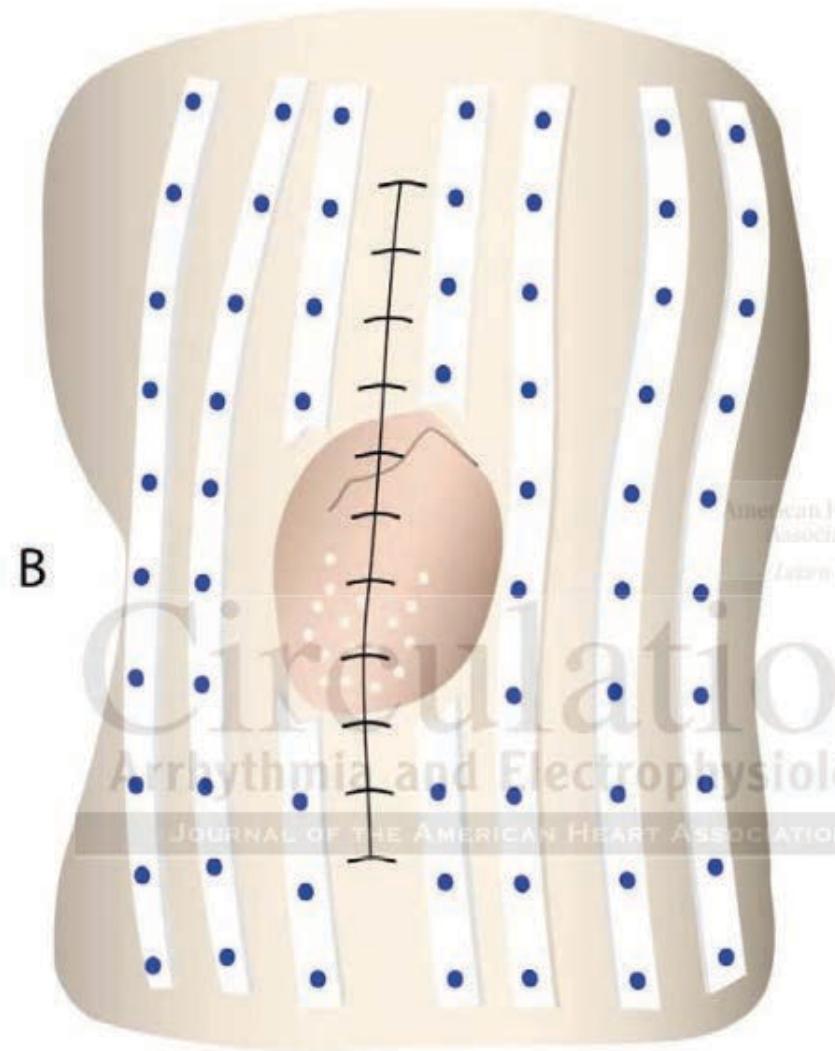
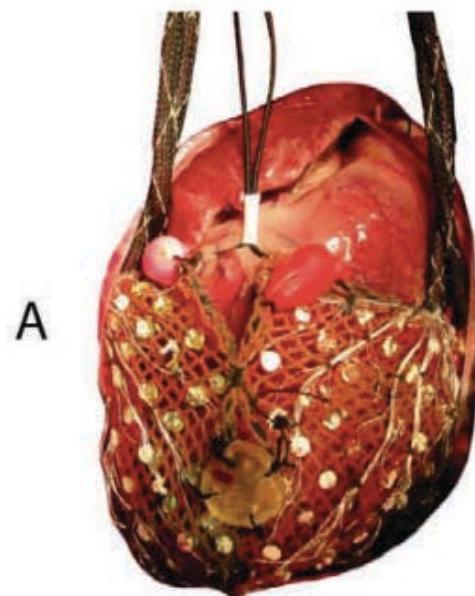


Nagata, Japanese Heart Journal, 1970.

Physical Phantoms

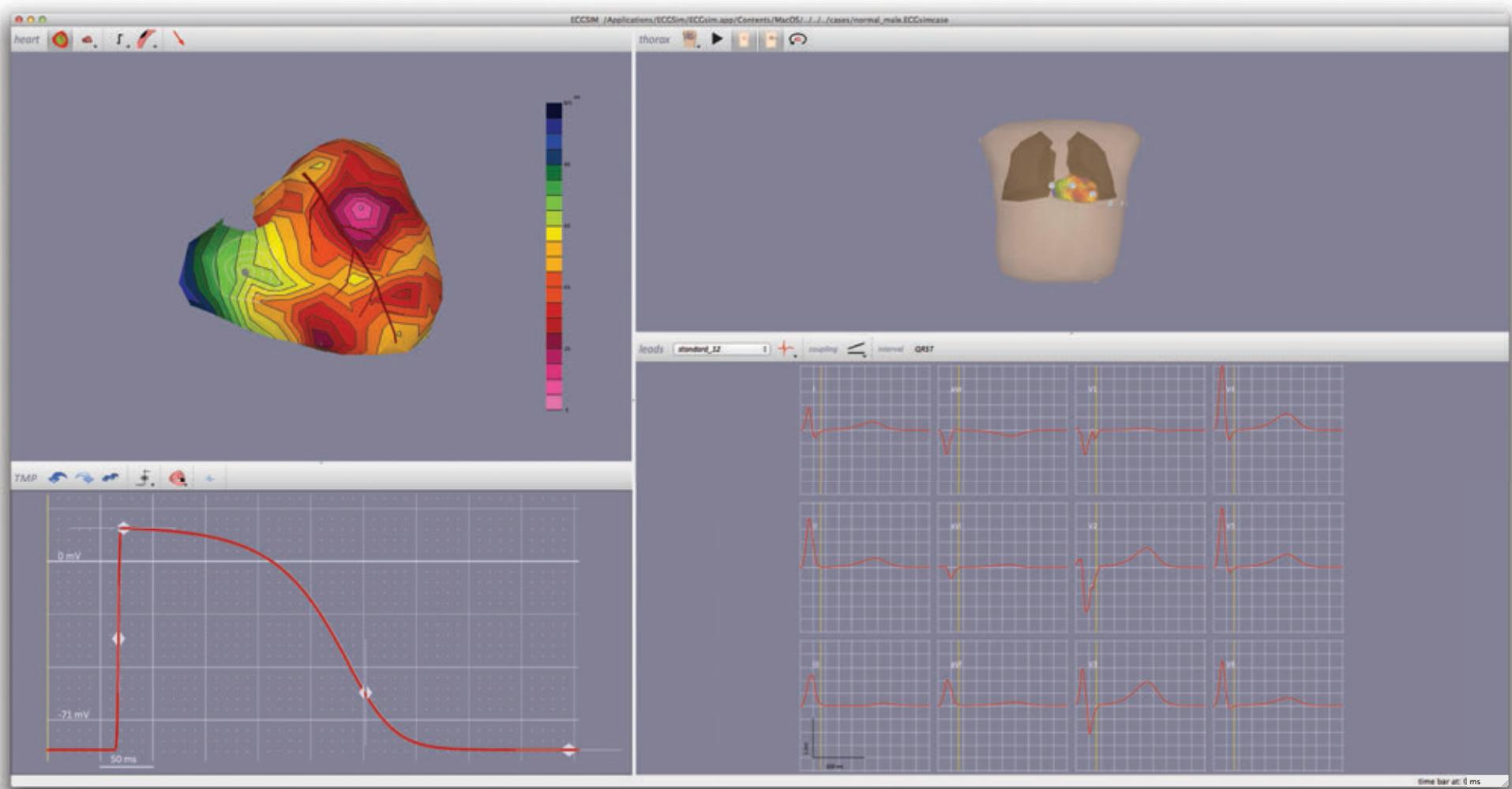


Animal Phantoms



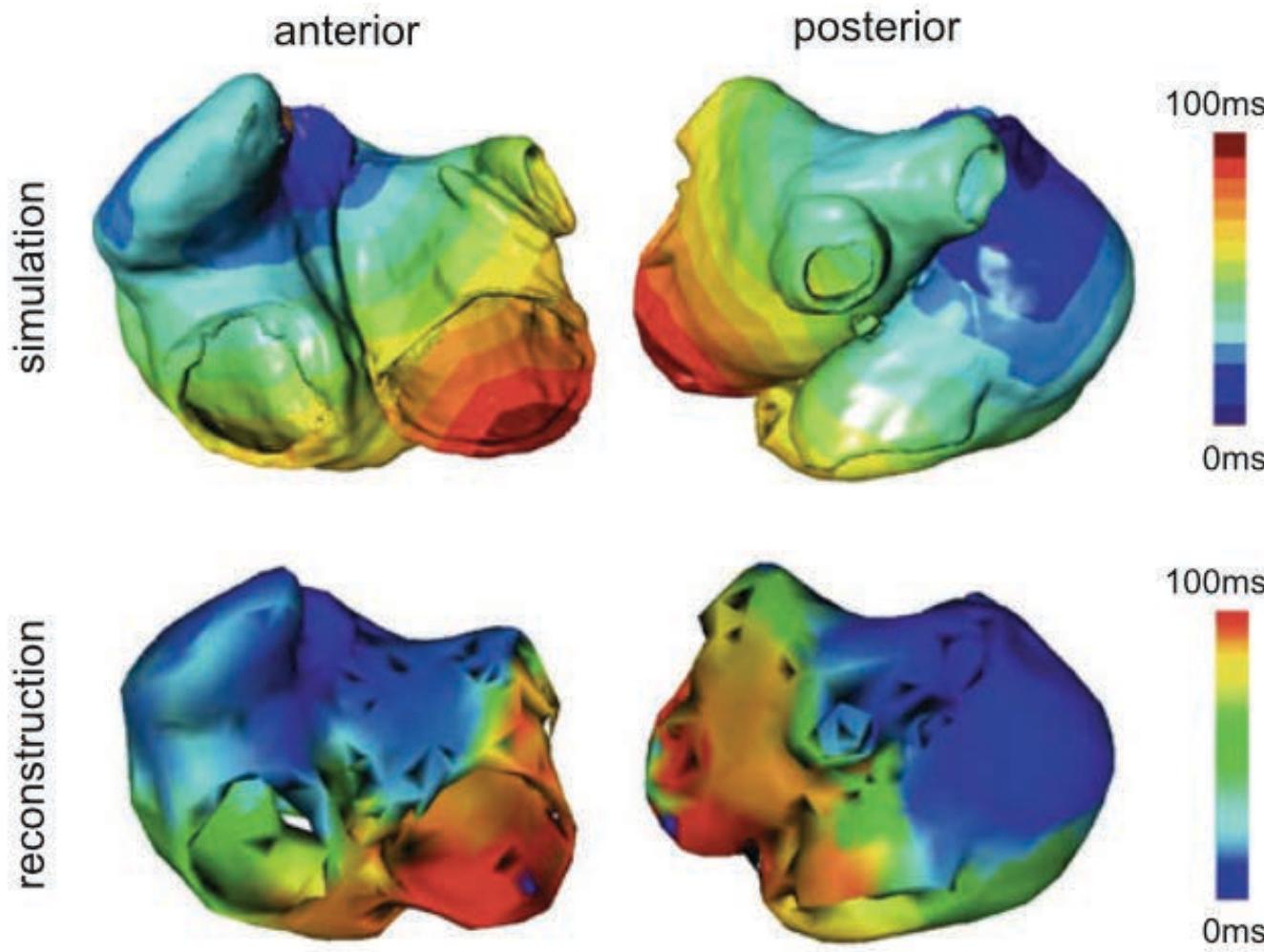
Bear L, et al. Circ Arrhythm Electrophysiol, 2015

Computational Models



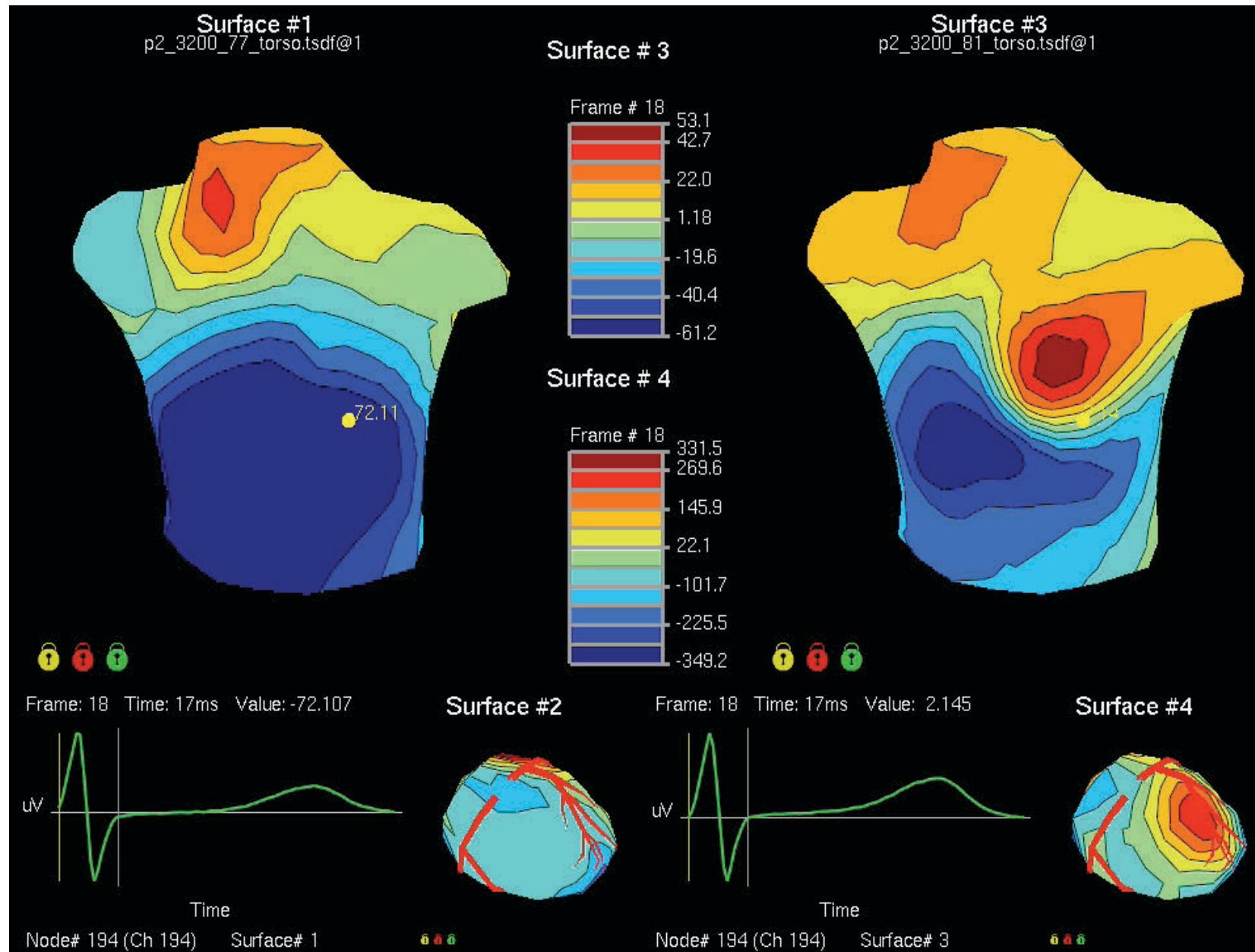
 **ECGBIM**

Computational Models

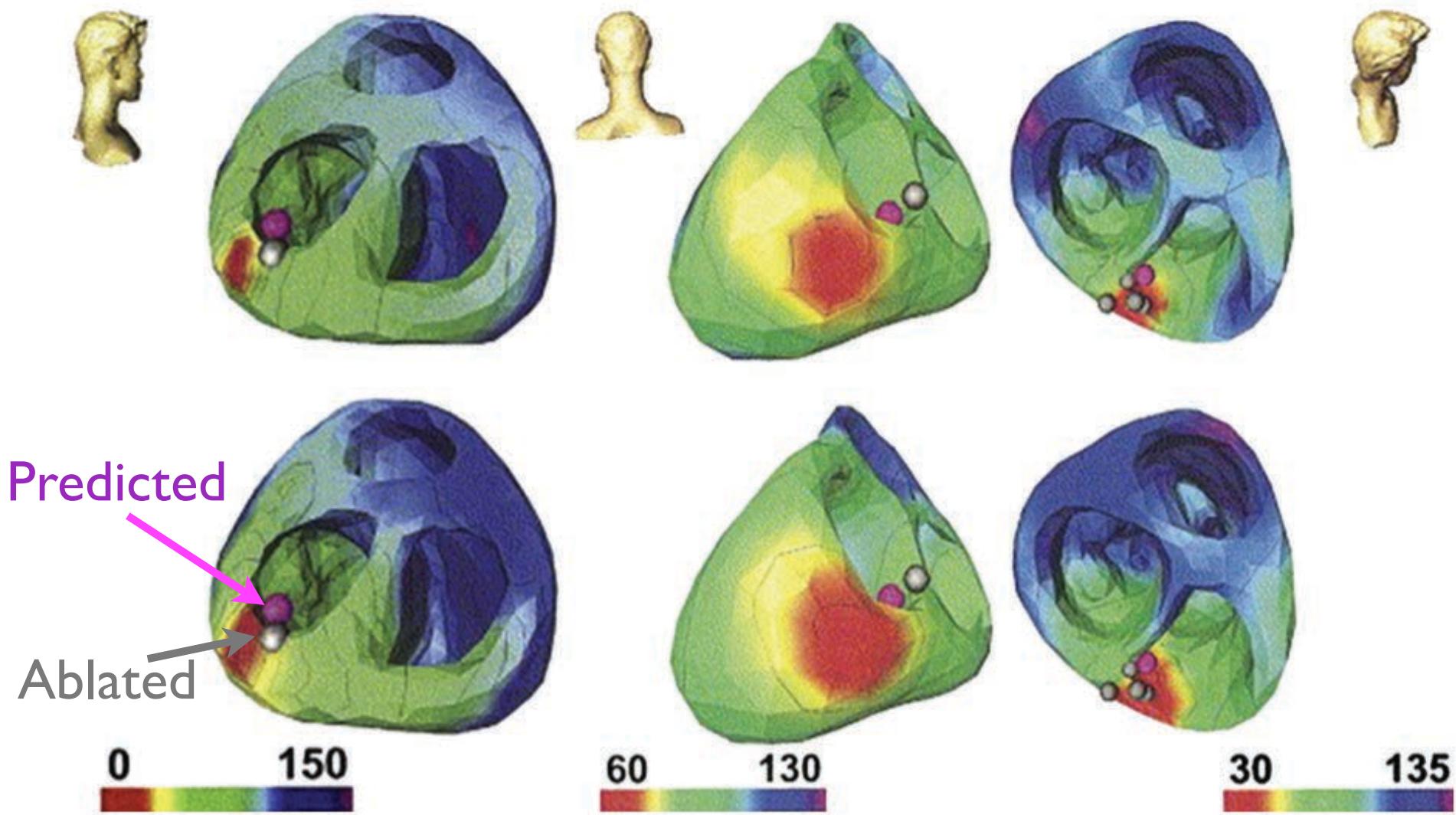


Krueger et al., Med Biol Eng Comput (2013) 51:1251–1260

Clinical Validation

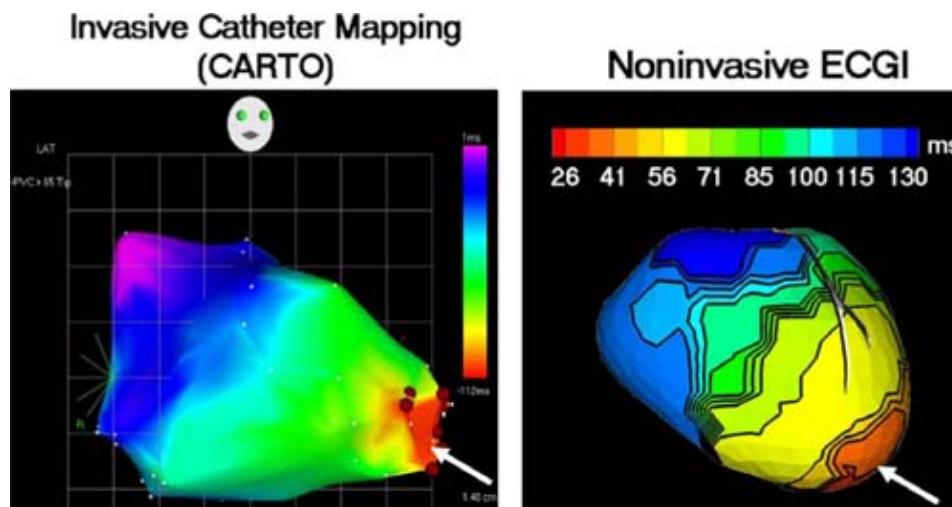
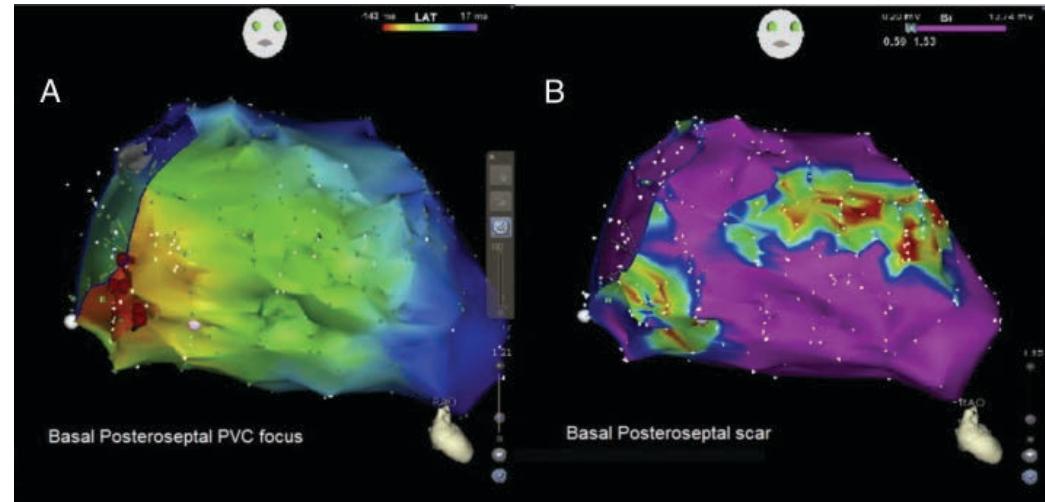
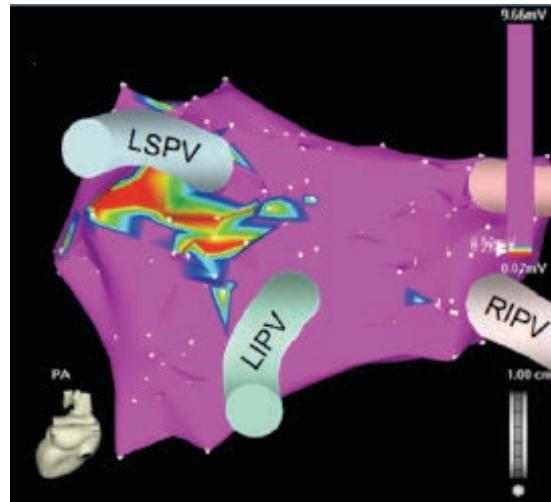


Clinical Validation



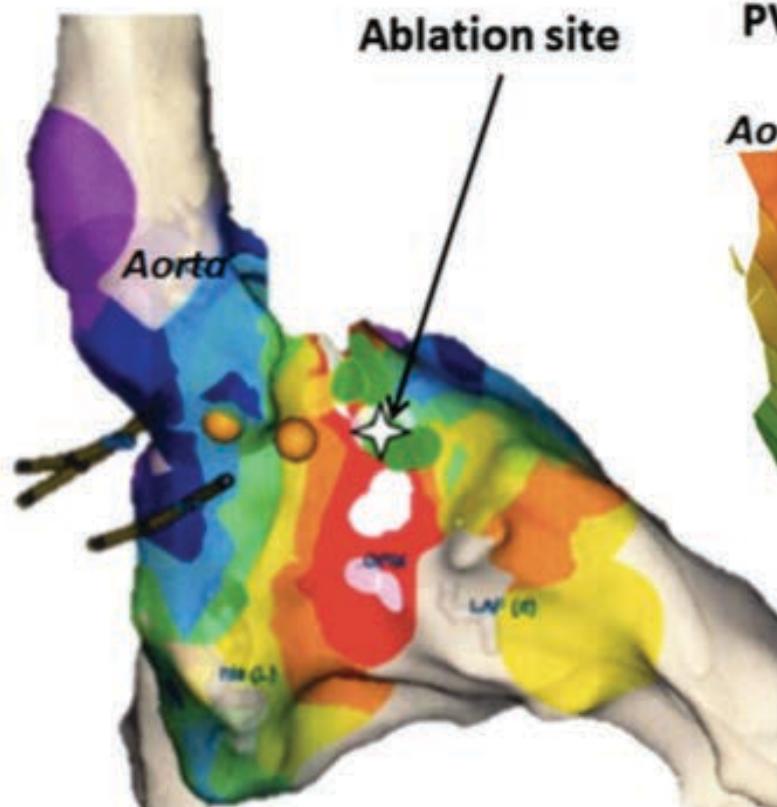
Berger T, et al.. J Am Coll Cardiol 2006;48(10):2045–52

Clinical Validation

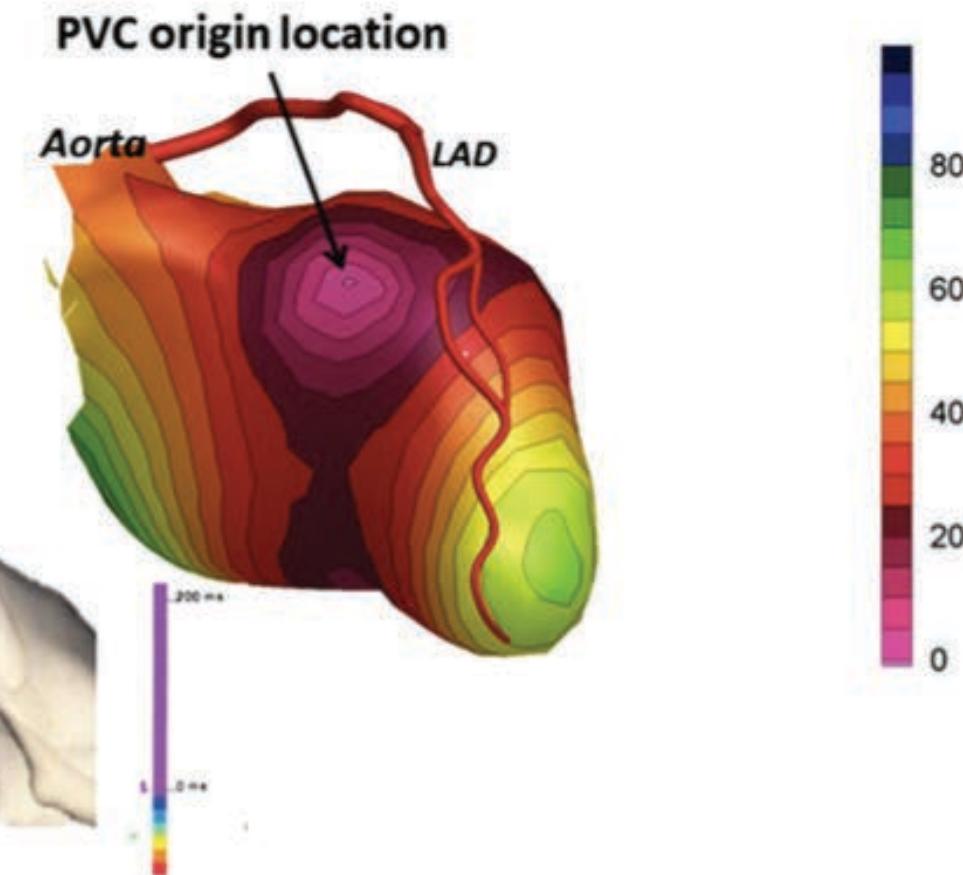


Clinical Validation

Electro anatomical map



12 lead activation map



van Dam et al. J. Electrocardiology 46 (2013) 574–579

The Metrics: How Should We Compare?



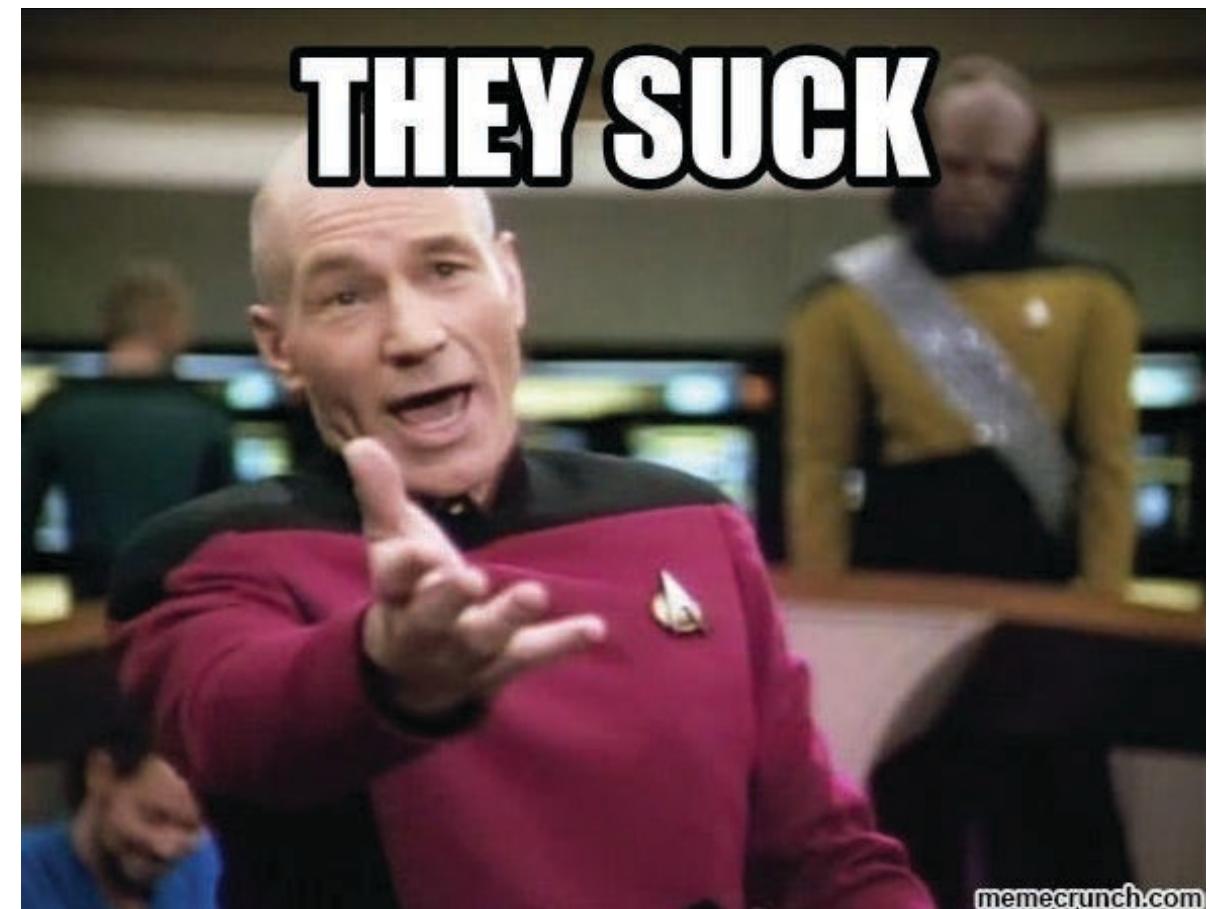
Statistical Metrics

Correlation Coefficient

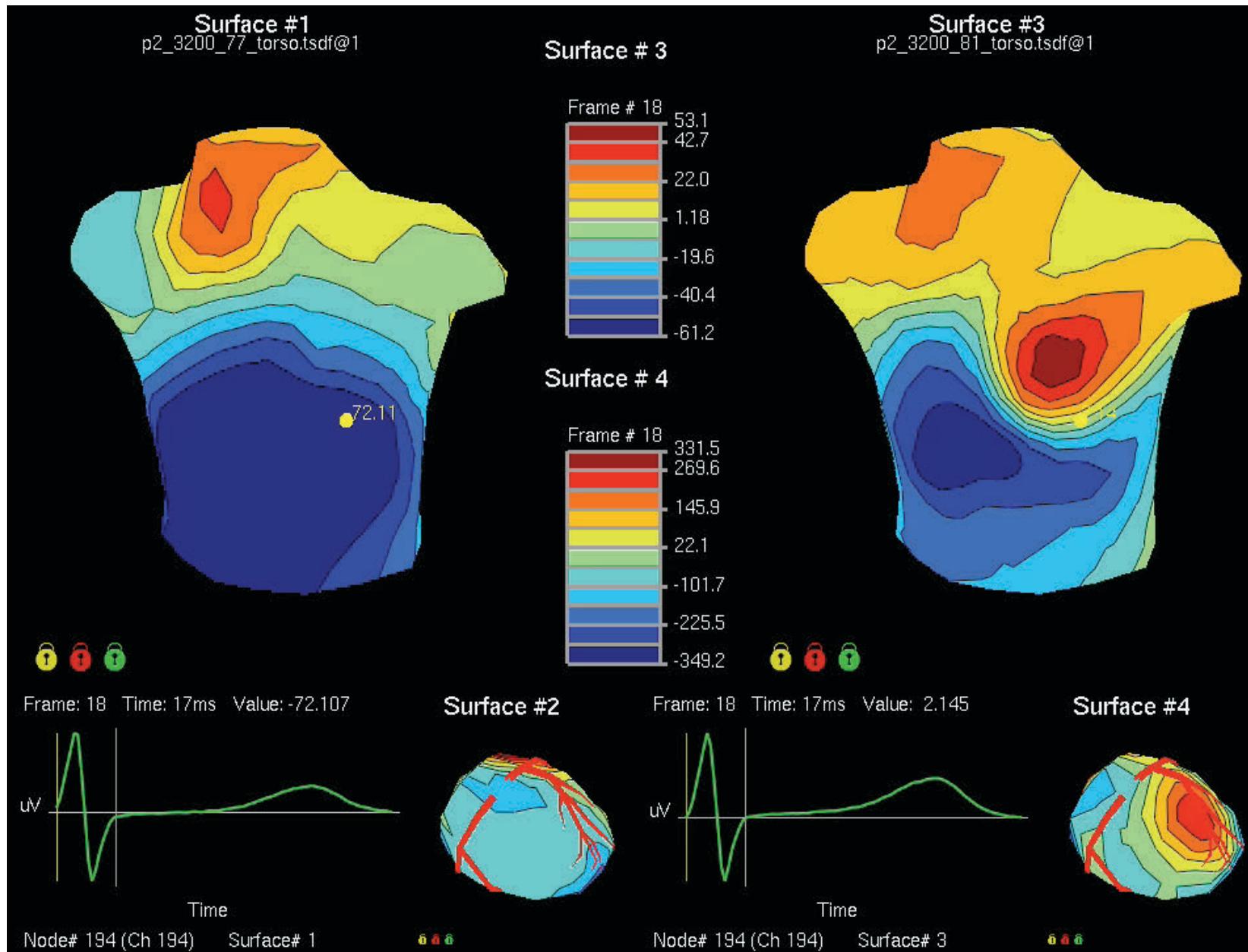
RMS Error

Relative Error

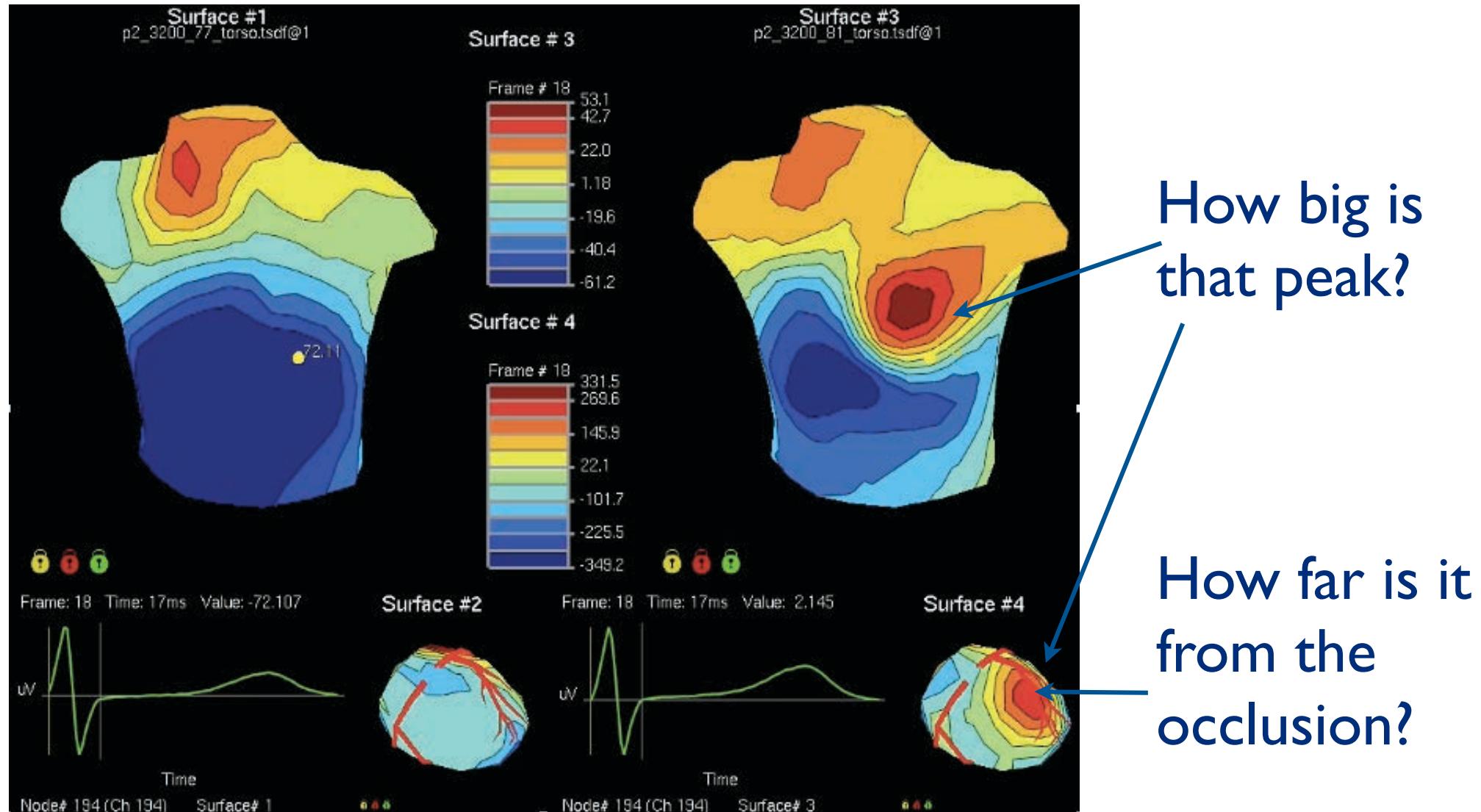
Maximum Error



Qualitative Comparison

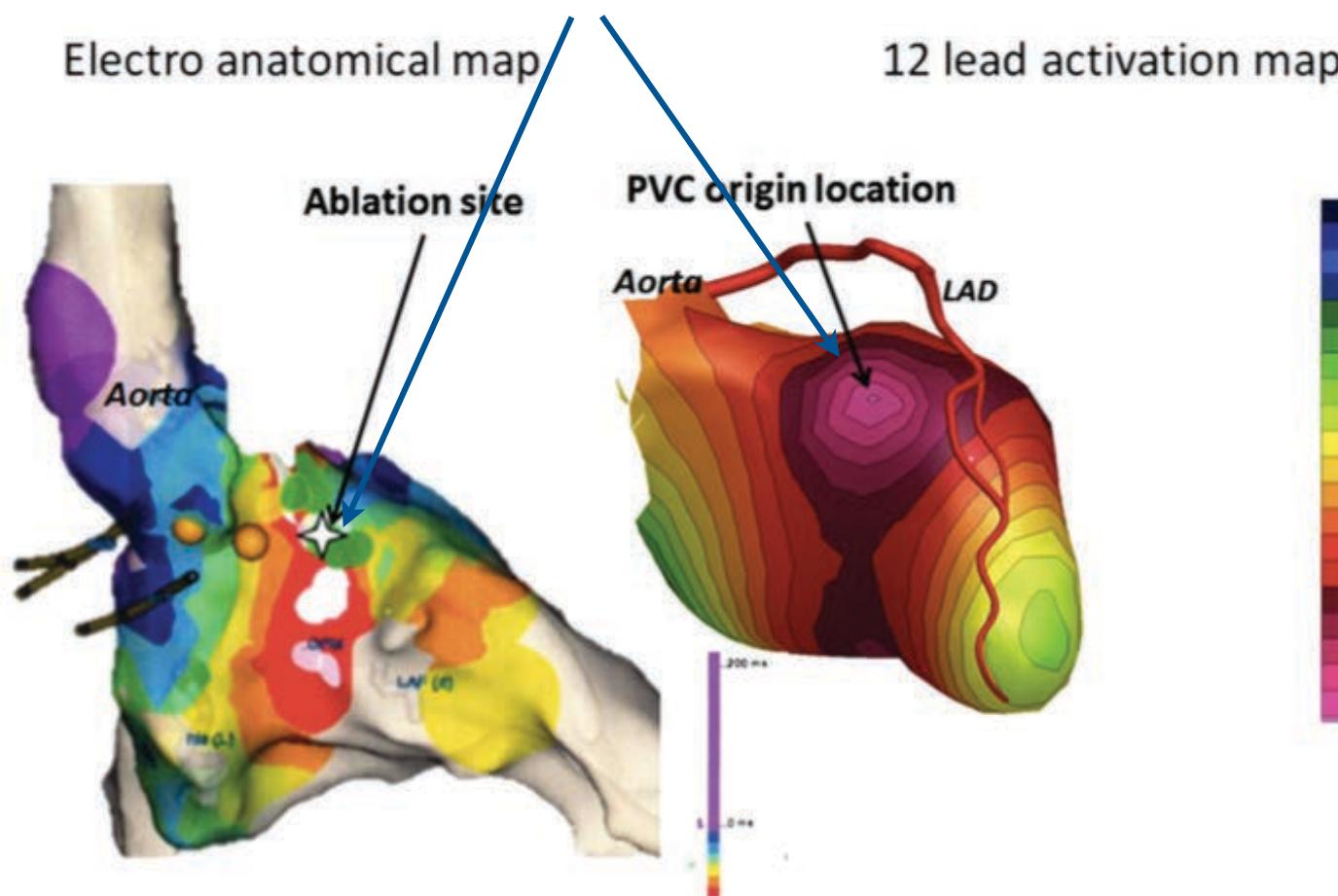


Hybrid Metrics



Clinical Metrics

How far apart are these locations?

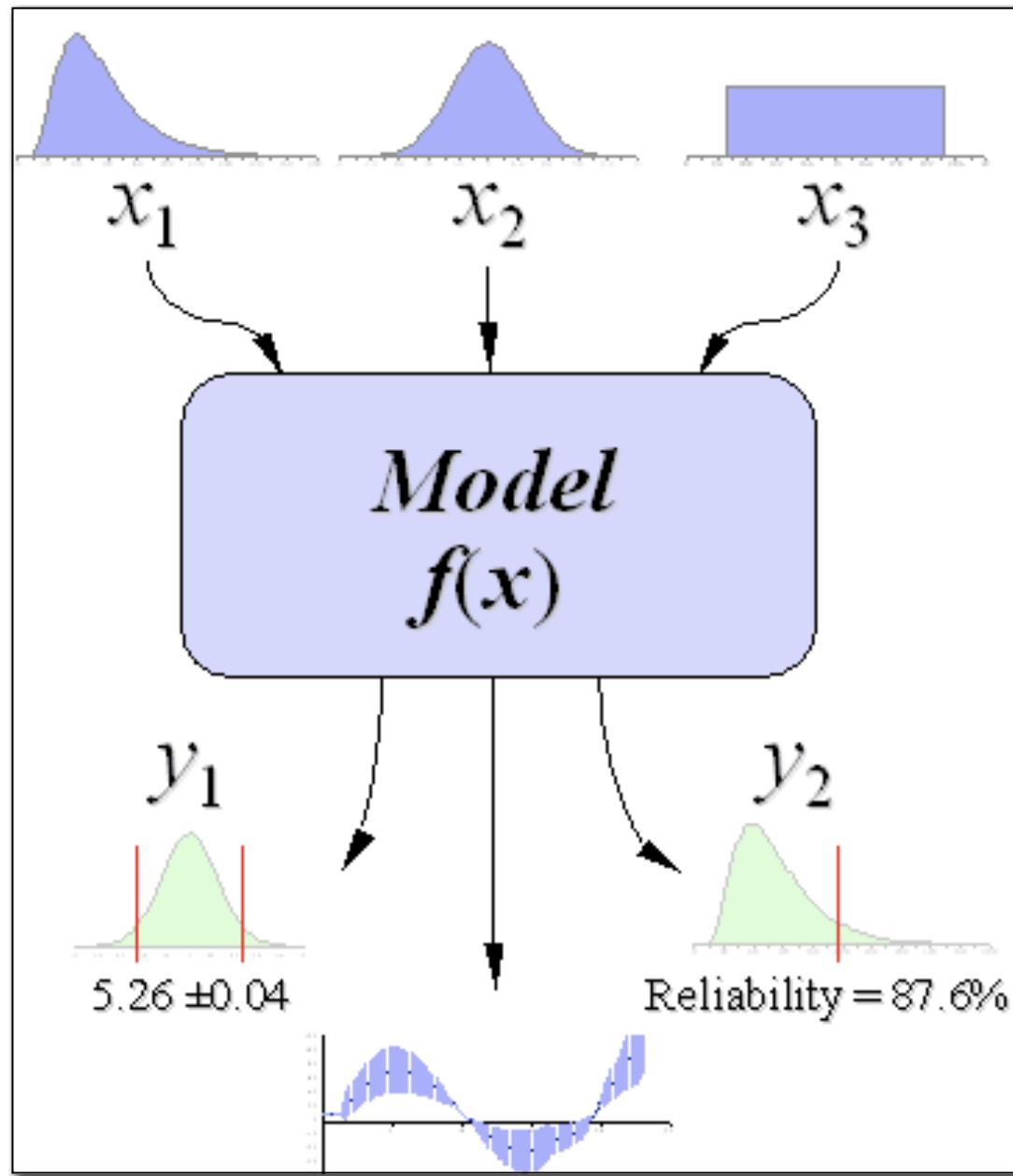


van Dam et al. J. Electrocardiology 46 (2013) 574–579

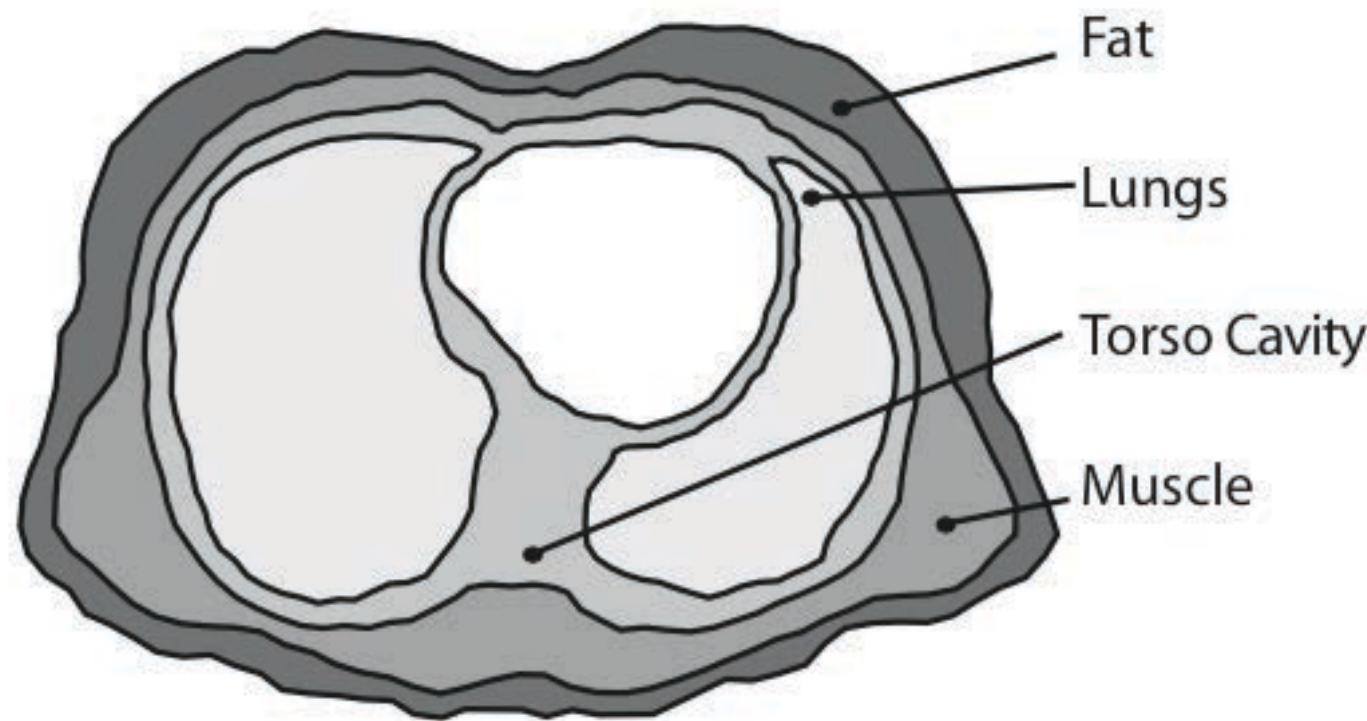
Uncertainty Quantification: Capturing more than Error



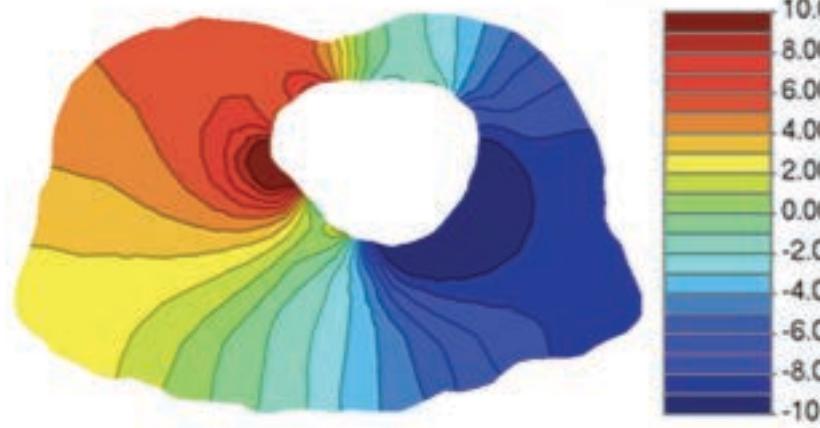
Quantifying Uncertainty



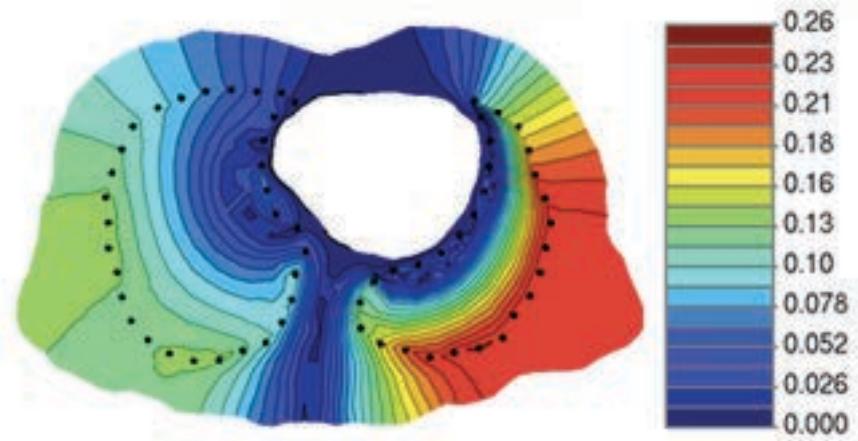
Study I: Variation in Conductivity



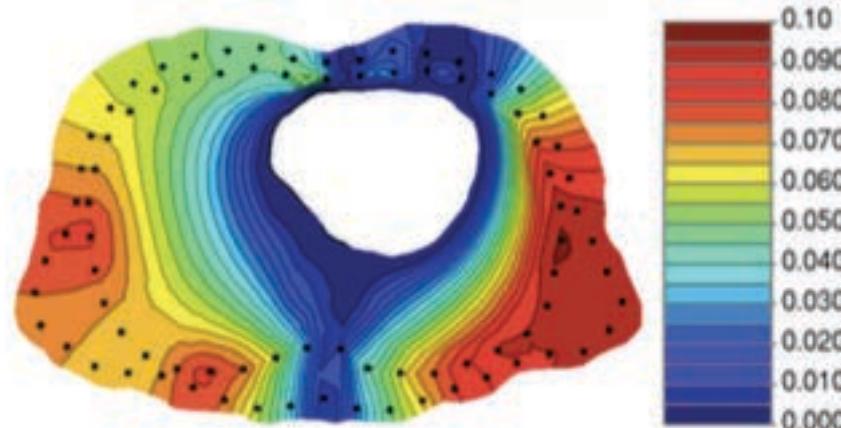
Results in 2D



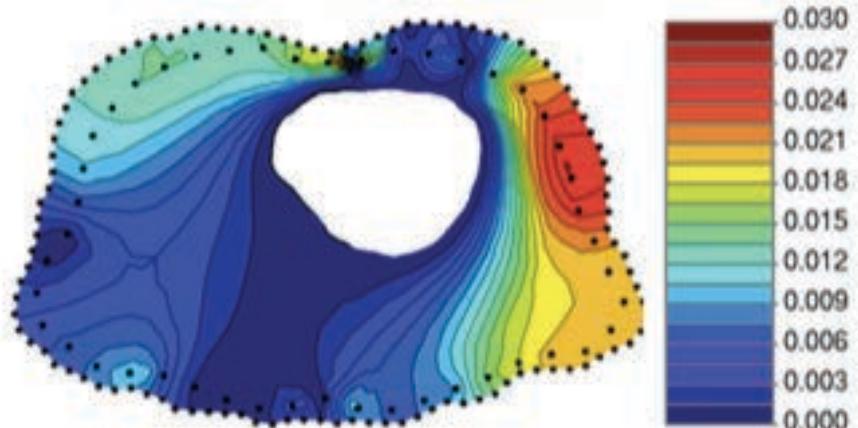
(a) Mean for $\pm 50\%$ lung conductivity



(b) Standard deviation for $\pm 50\%$ lung conductivity



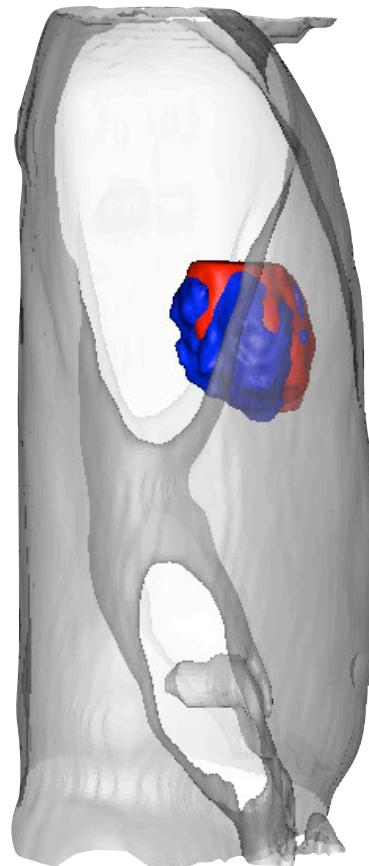
(c) Standard deviation for $\pm 50\%$ muscle conductivity



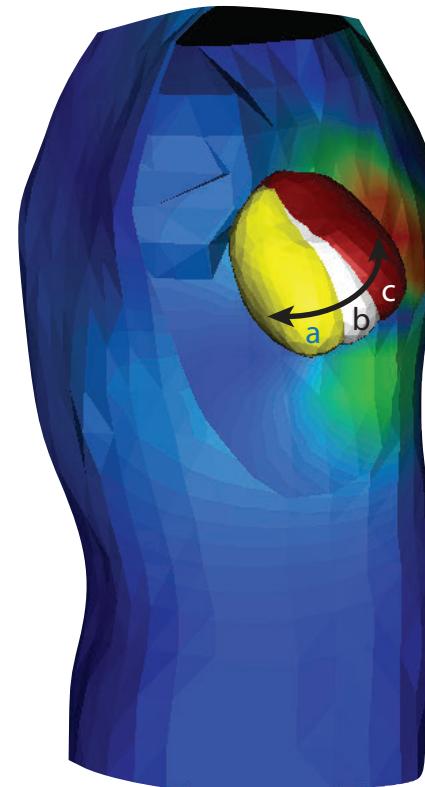
(d) Standard deviation for $\pm 50\%$ fat conductivity

Study 2: Respiratory Heart Motion

Supine to Prone



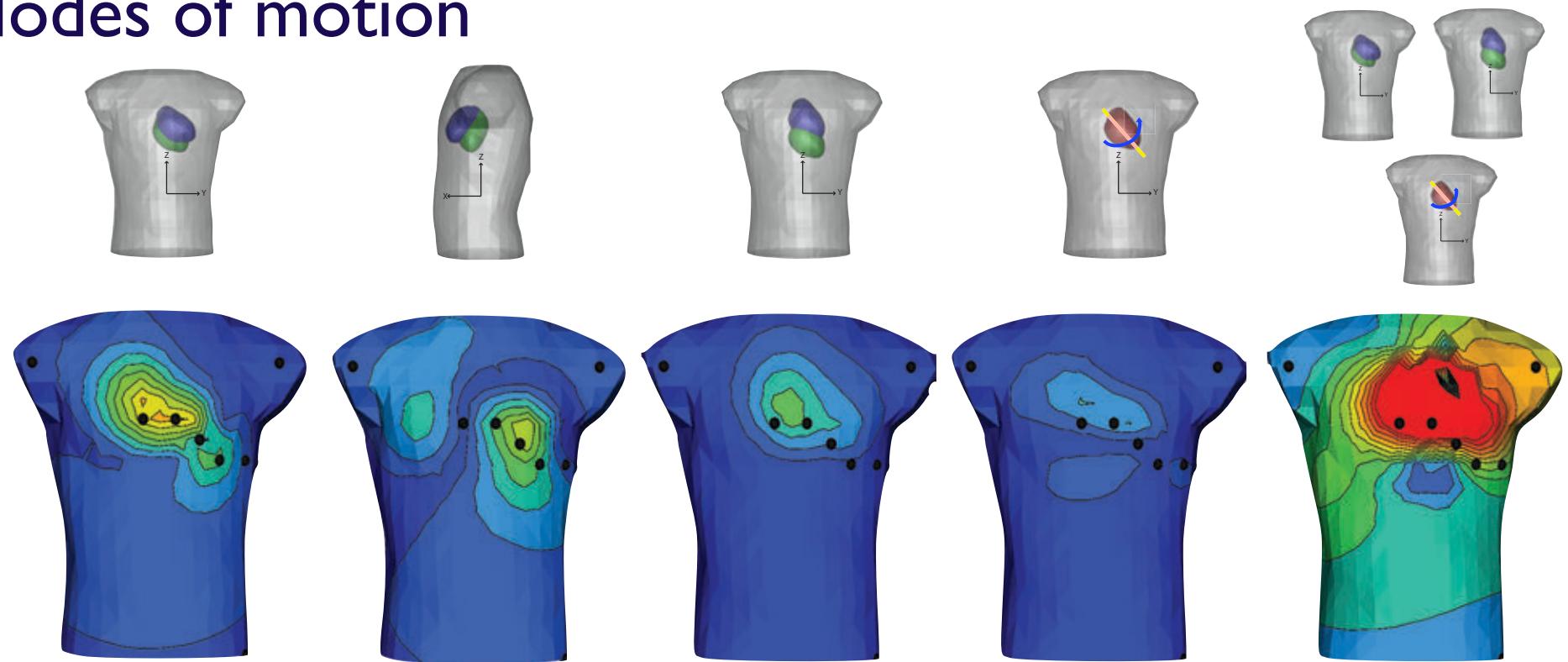
Pendulum motion
Pivot 30



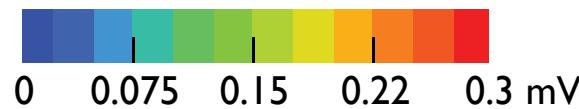
D.J. Swenson, S.E. Geneser, J.G. Stinstra, R.M. Kirby, and R.S. MacLeod. Cardiac Position Sensitivity Study in the Electrocardiographic Forward Problem Using Stochastic Collocation and BEM. *Ann. Biomed. Eng.*, 39(12):2900–2910, 2011.

Results

Modes of motion



Standard Deviation



We Need to Work Together



Time to Meet 2004



Available online at www.sciencedirect.com



Journal of Electrocardiology 38 (2005) 385–399

JOURNAL OF
Electrocardiology

www.elsevier.com/locate/jelectrocard

Report of the first virtual visualization of the reconstructed electrocardiographic display symposium

Rob MacLeod^{a,*}, Fred Kornreich^b, Adriaan van Oosterom^c, Pentti Rautaharju^d, Ron Selvester^e,
Galen Wagner^f, Christoph Zywietz^g

VRED, Meeting, 2004



Ron Selvester,
1922-2015

Time to Meet 2015

ECG Imaging 2015



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Welcome to ECG Imaging 2015

Welcome

25th to 28th of March, 2015

First CEI Meeting,
Herrenalb, Germany, 2015

CEI 2015



Sharing Data Phase I



Sharing Data Phase II



University of Utah

Center for Clinical and Translational Sciences

Center for Clinical and Translational Science

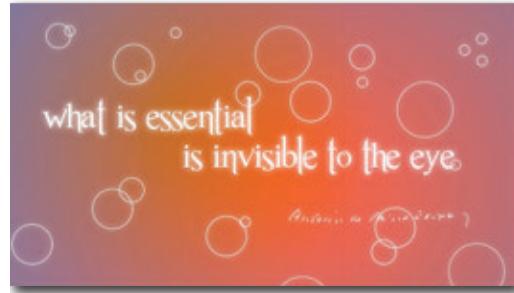
Edgar Time Signals

Experiment:

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Institution	<input type="radio"/> University of	Ischemia			
	<input type="radio"/> Other	VF			
		AF			
		Defibrillation			
		Pacing			
		In Situ			
		Open Chest			
	<input type="button" value="search"/>	Parameters	Select		

record	Experiment	Time Signals File	Mesh File	Images File	Registration File	Documentation File
1	In Situ Swine Experiment	79567		79565	79566	79564
2	RSM-13-11-05	79588	79589	79586	79587	79584
3	RSM-13-11-11	79765	79763	79762	79764	79761

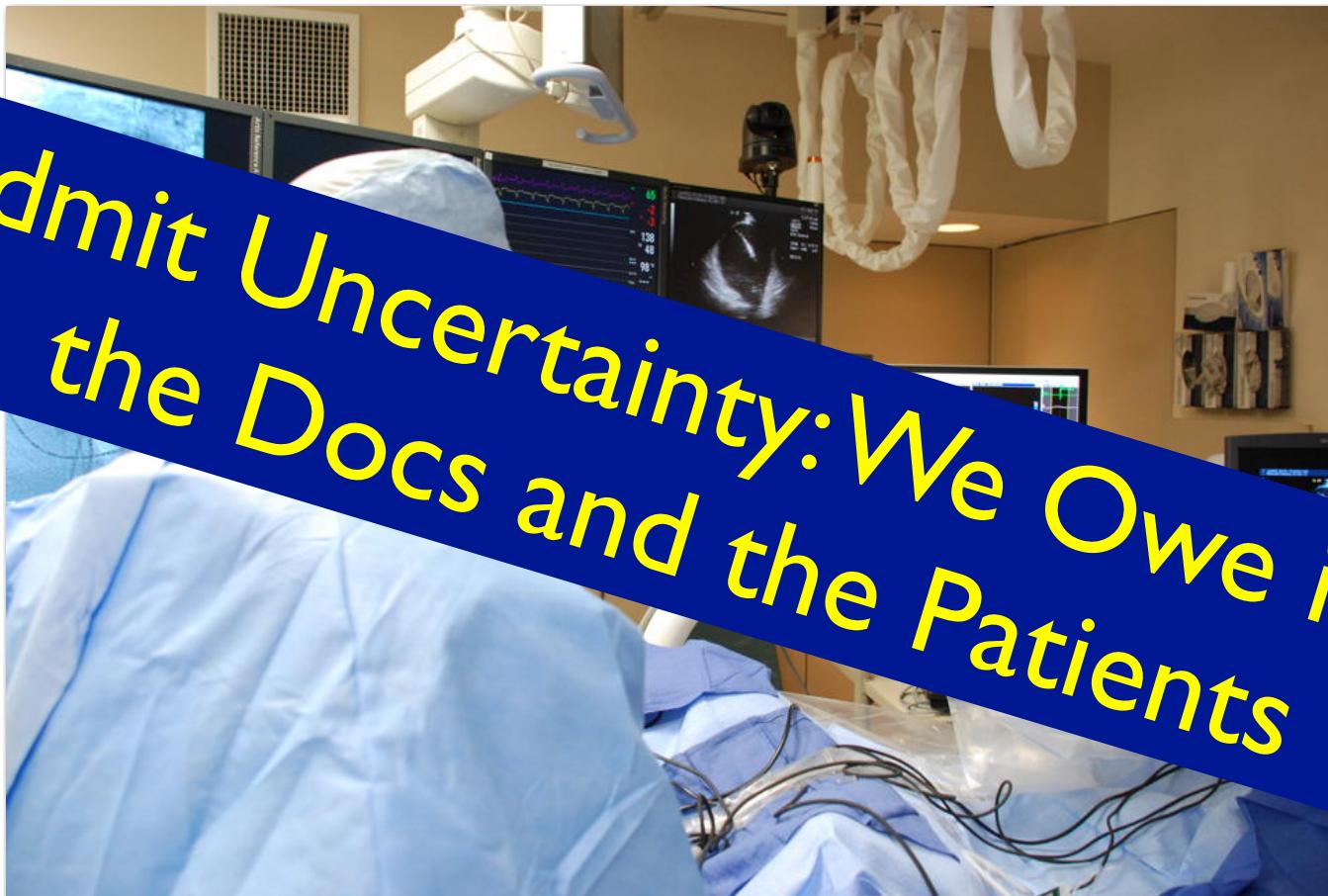
Back to the Message



Evaluation Rocks



*Admit Uncertainty: We Owe it to
the Docs and the Patients*



And We Have to Do it Together



CONSORTIUM FOR ECG IMAGING (CEI)

Consortium for ECG Imaging

Consortium for ECG Imaging

Conferences

[ECG Imaging 2015](#)

[ISCE 40th Annual Conference](#)

[Computing in Cardiology 2015](#)

Related Societies

[Computing in Cardiology](#)

[International Society of Electrocardiology](#)

[International Society for Computerized Electrocardiology](#)



To Learn More

CONSORTIUM FOR ECG IMAGING (CEI)

www.ecg-imaging.org



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www.cinc2015.org