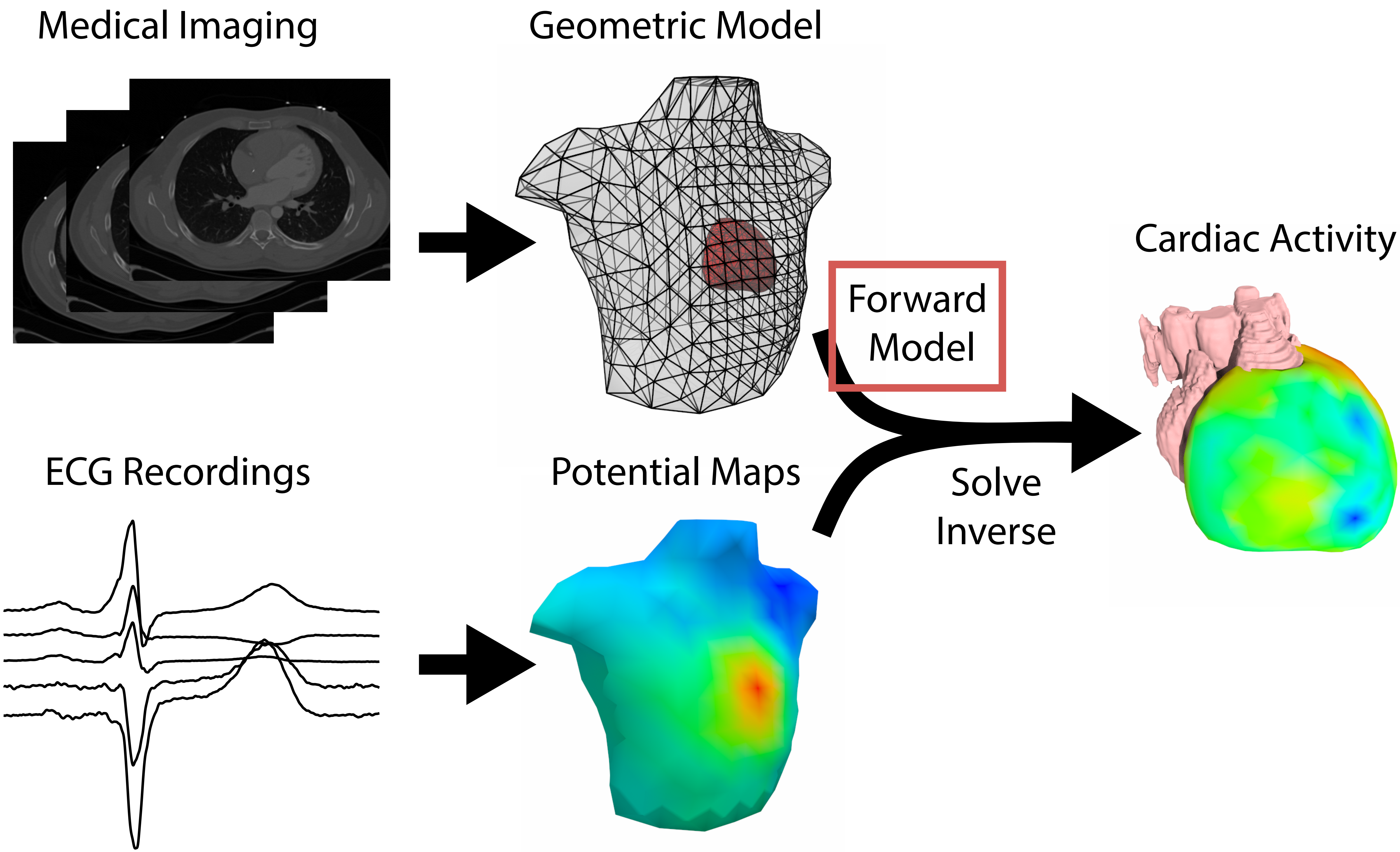
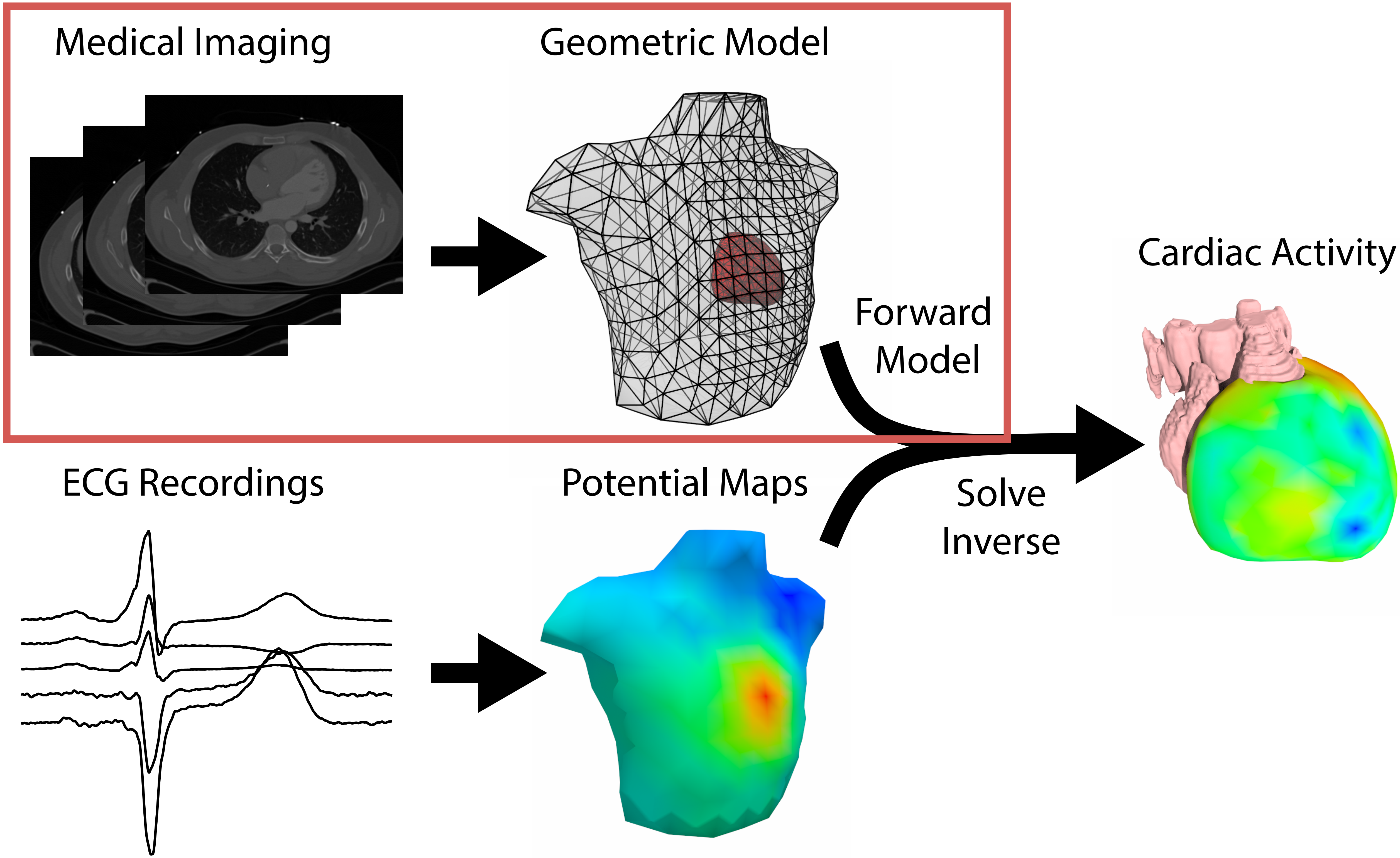
The Effect of Patient-Specific Cardiac Anatomical Models on ECGI Accuracy

Jess Tate

ECG Imaging


Medical Imaging
Geometric Model
Cardiac Activity
Forward Model
ECG Recordings
Potential Maps
Solve Inverse

ECG Imaging


Medical Imaging
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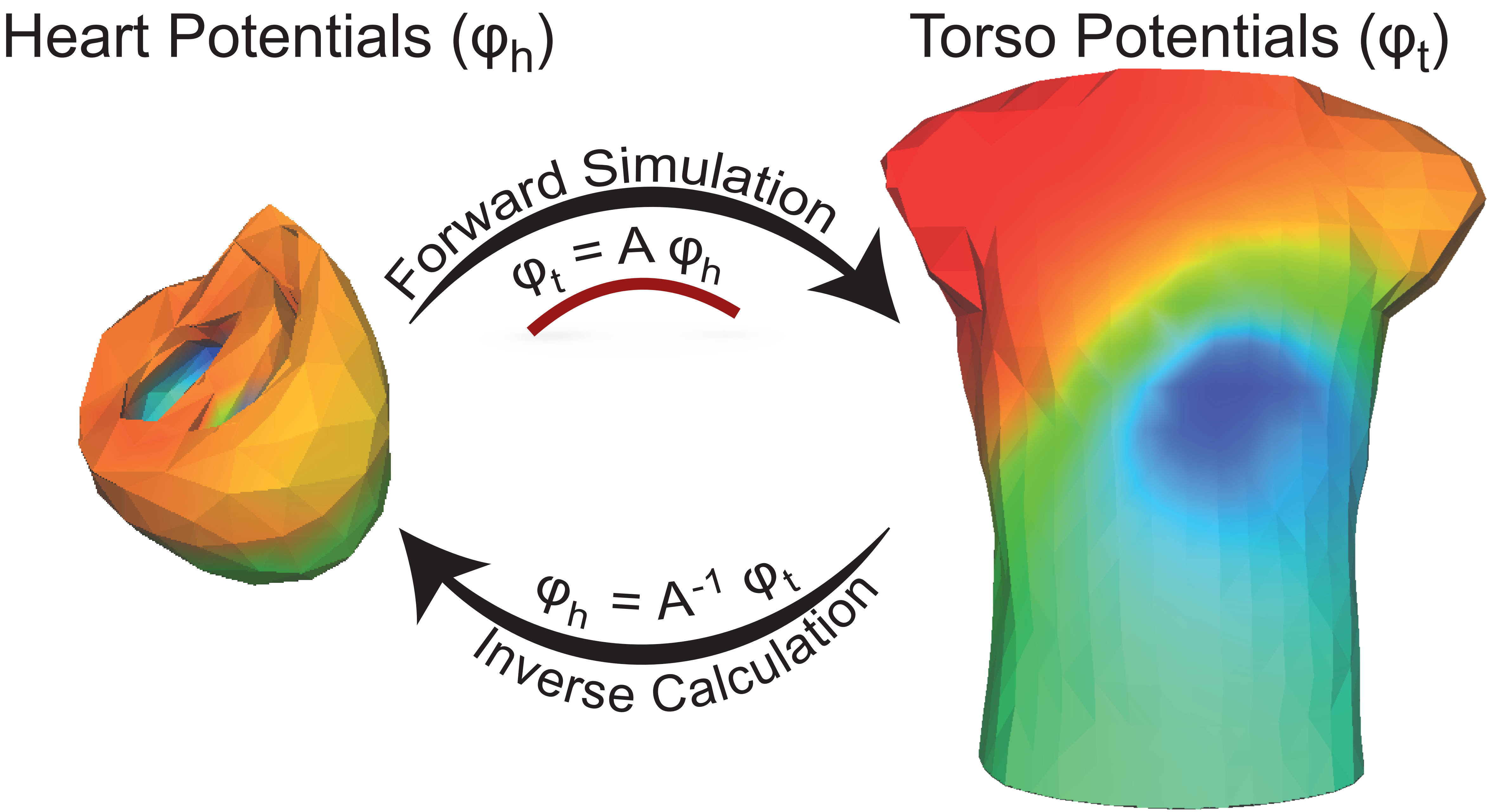
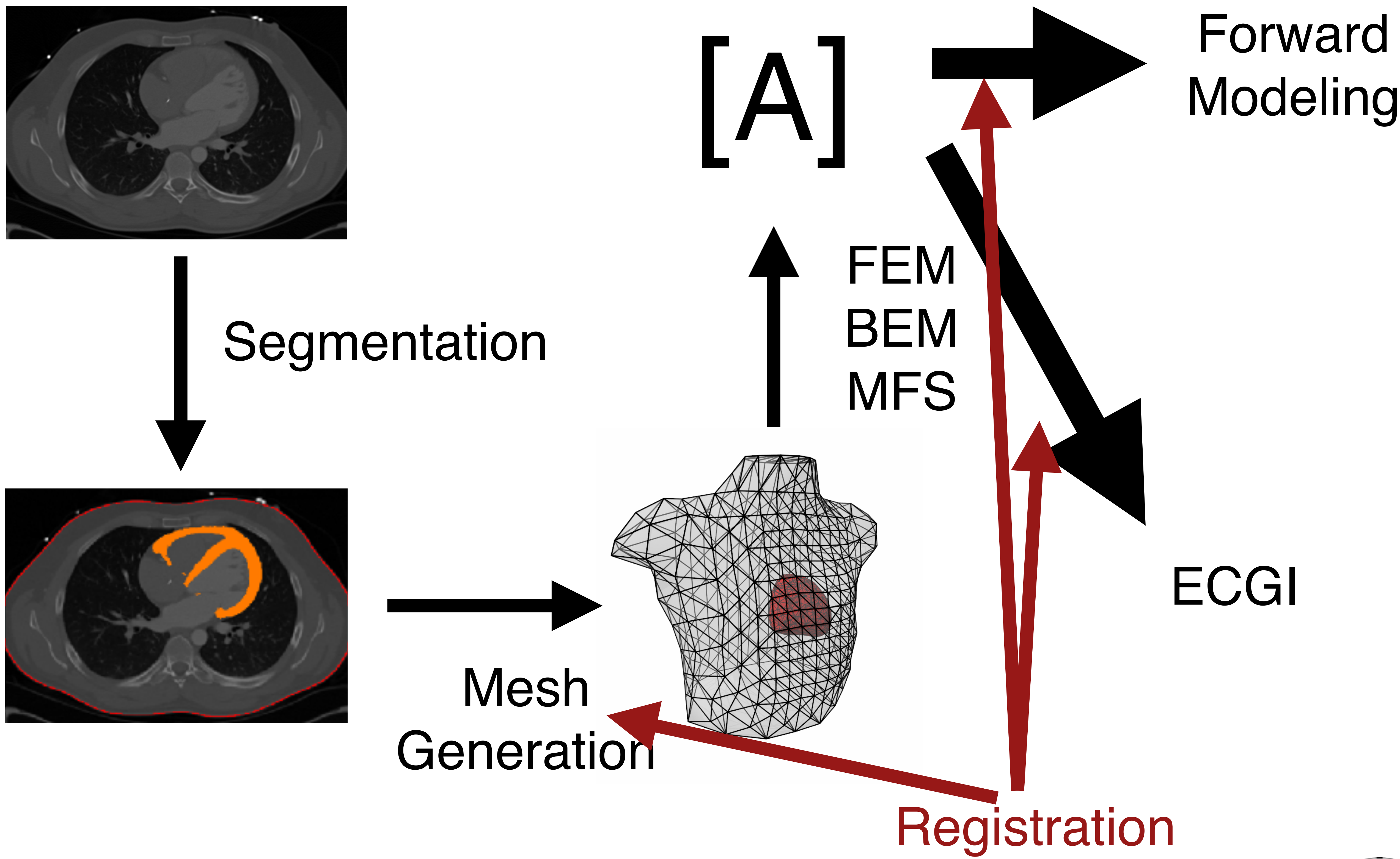
ECG Imaging



ECG Imaging Relies on Accurate Forward Models

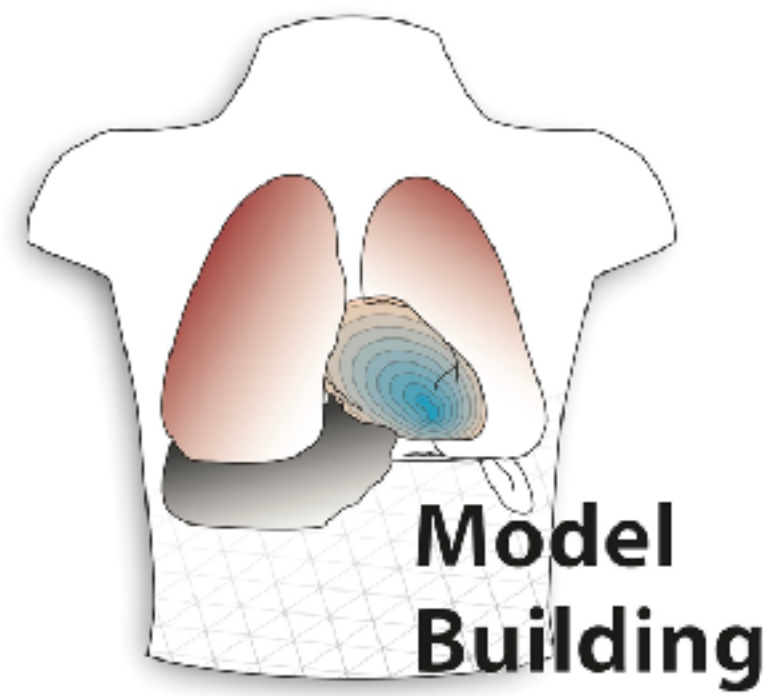
Modeling Pipeline



Improving Model Generation

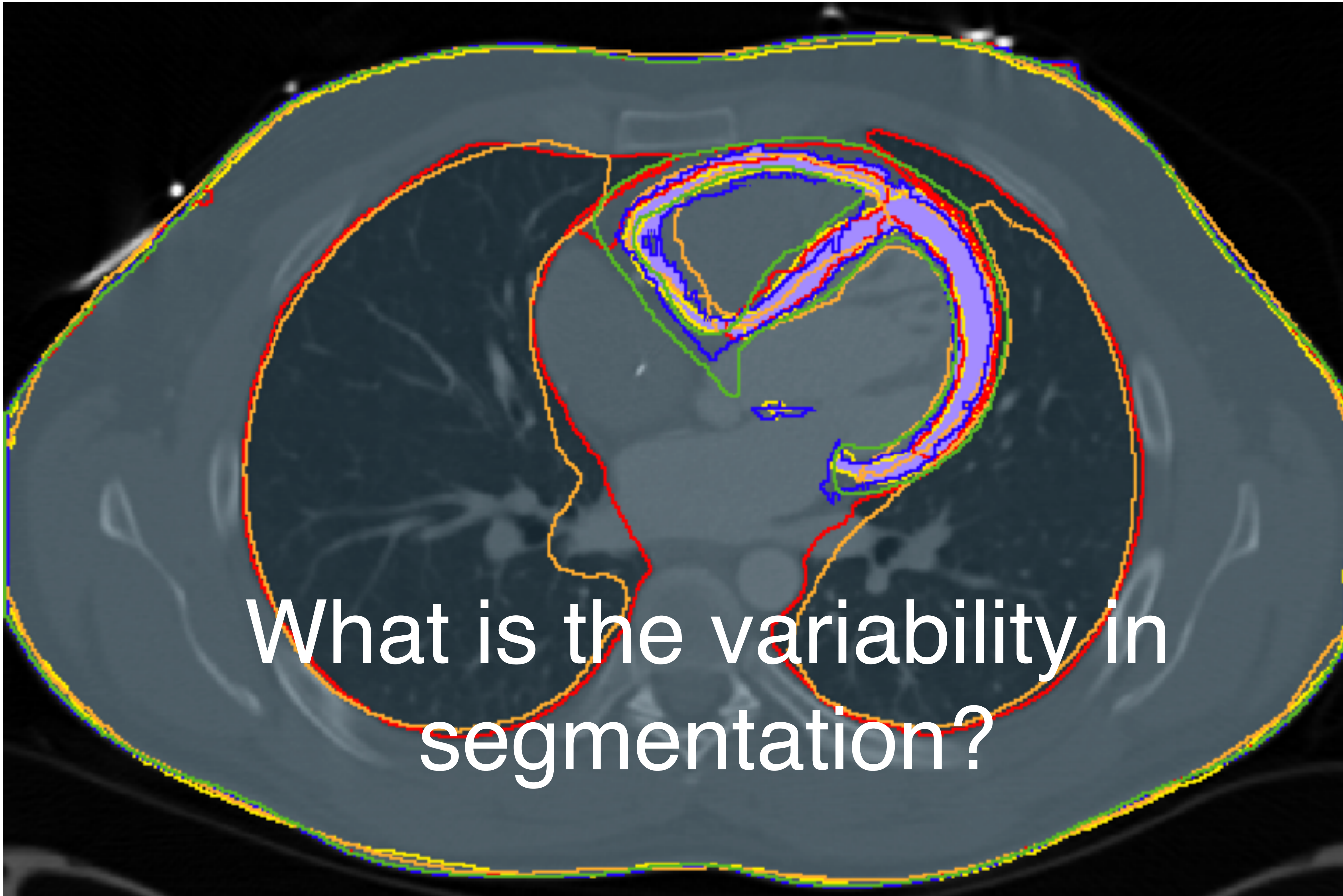
Segmentation

CEI: Modeling Error Workgroup
(Consortium for ECG Imaging)



Workgroup is to identify/quantify errors and uncertainties

Segmentation Error



Data Collection

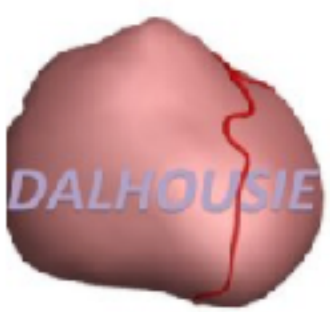
Covalic

Secure | https://challenge.kitware.com/#phase/57c76241cad3a51cc66c7e60

Jess Tate

CEI Model Building > **Stage 1: Dalhousie Segmentation**

OVERVIEW



This phase is to upload the segmentation of torso, ventricles, left lung, and right lung from the Dlahousie CT scan. Four files will need to be submitted simultaneously:

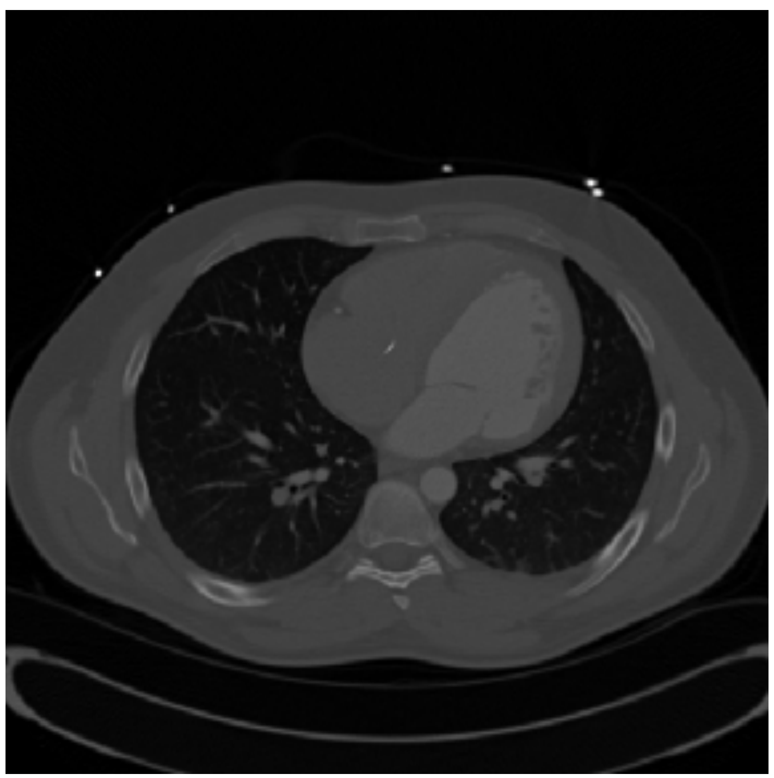
- LLung.nrrd - left lung
- RLung.nrrd - right lung
- Torso.nrrd - Torso surface (everything in the torso should be 1)
- Ventricles.nrrd - Ventricular Myocardium (with endo and epicardial surfaces)

Each file will need to be of the same image size and spacing as the original CT scan (512x512x54, 0.7422x0.7422x3). Select all of the files when in the file finder dialogue. You submission will be compared to a "Ground Truth" which is just one of the possible segmentations, so do not worry what your scores or metrics are, but if they are not calculated (it may take several minutes), or if there is an error, you will need to resubmit the segmentations. If you wish to, you can create an empty file (nrrd of the same size with all zeros) to skip one of the tissues. Once all the participants submit a segmentation of each of the tissues, we will create a common segmentation to use for the next stage.

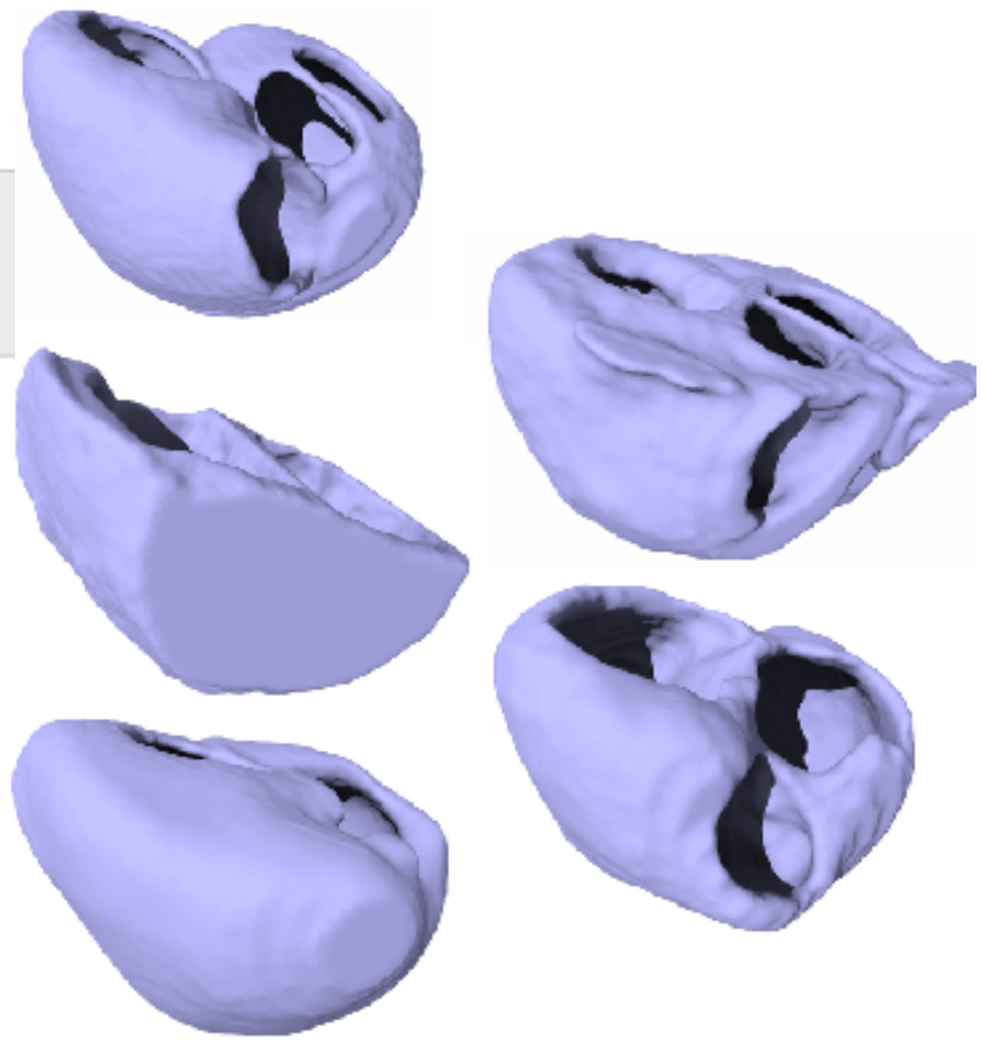
Download test dataset | Download ground truth data | Submit your results

LEADERBOARD

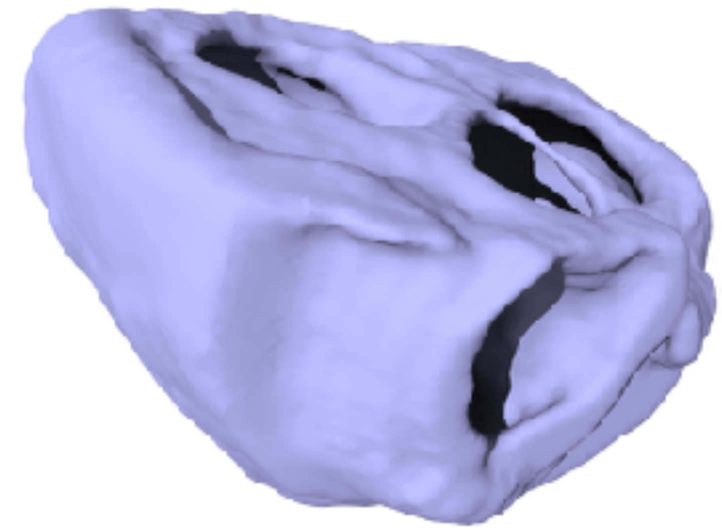
Segmentations



CT scan

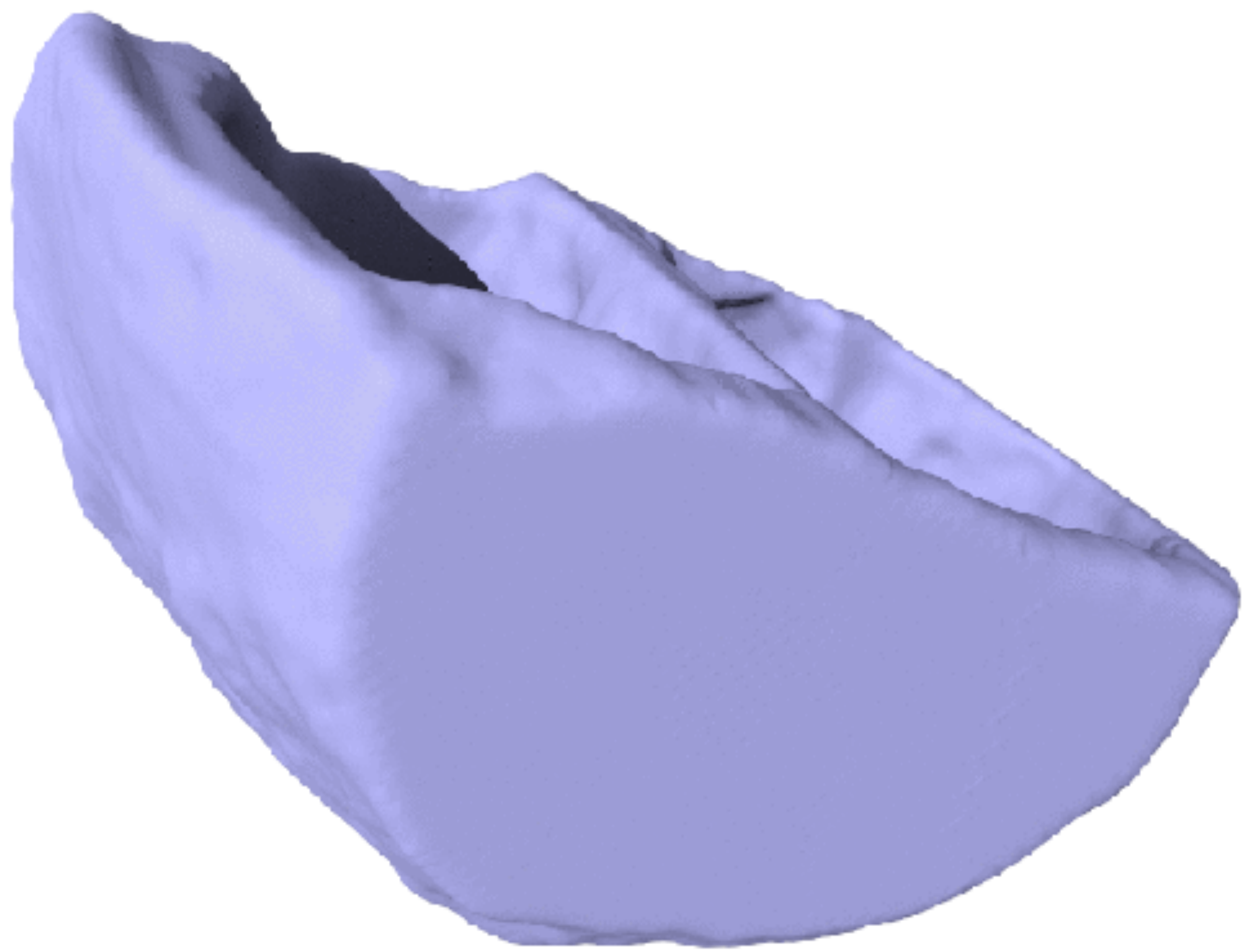


Covalic

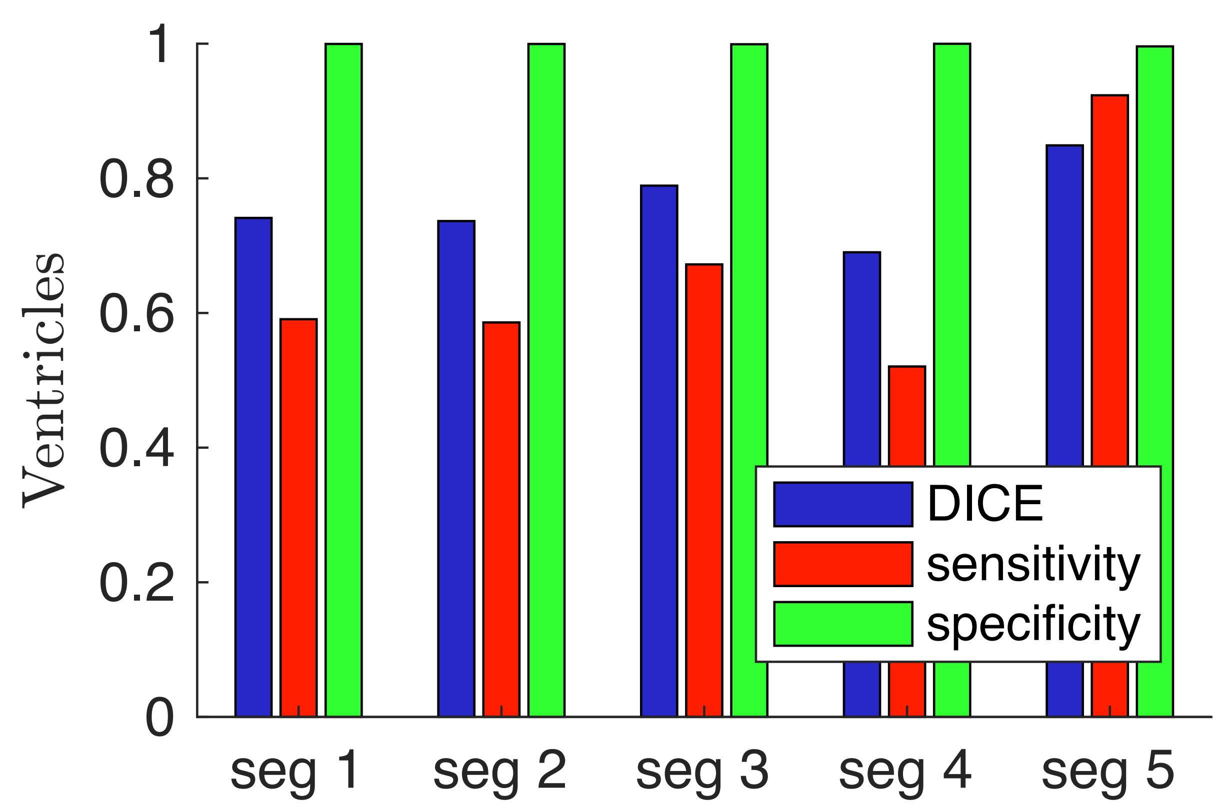


STAPLE

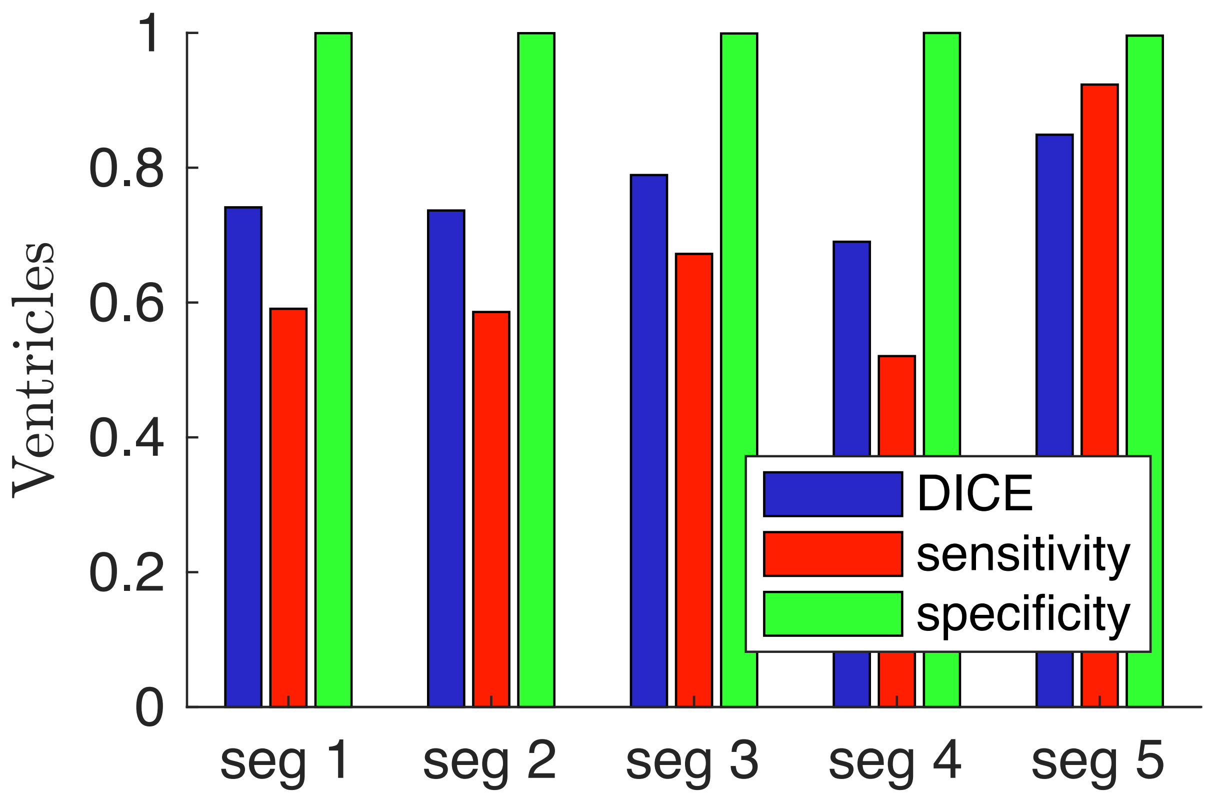
Segmentation Variation

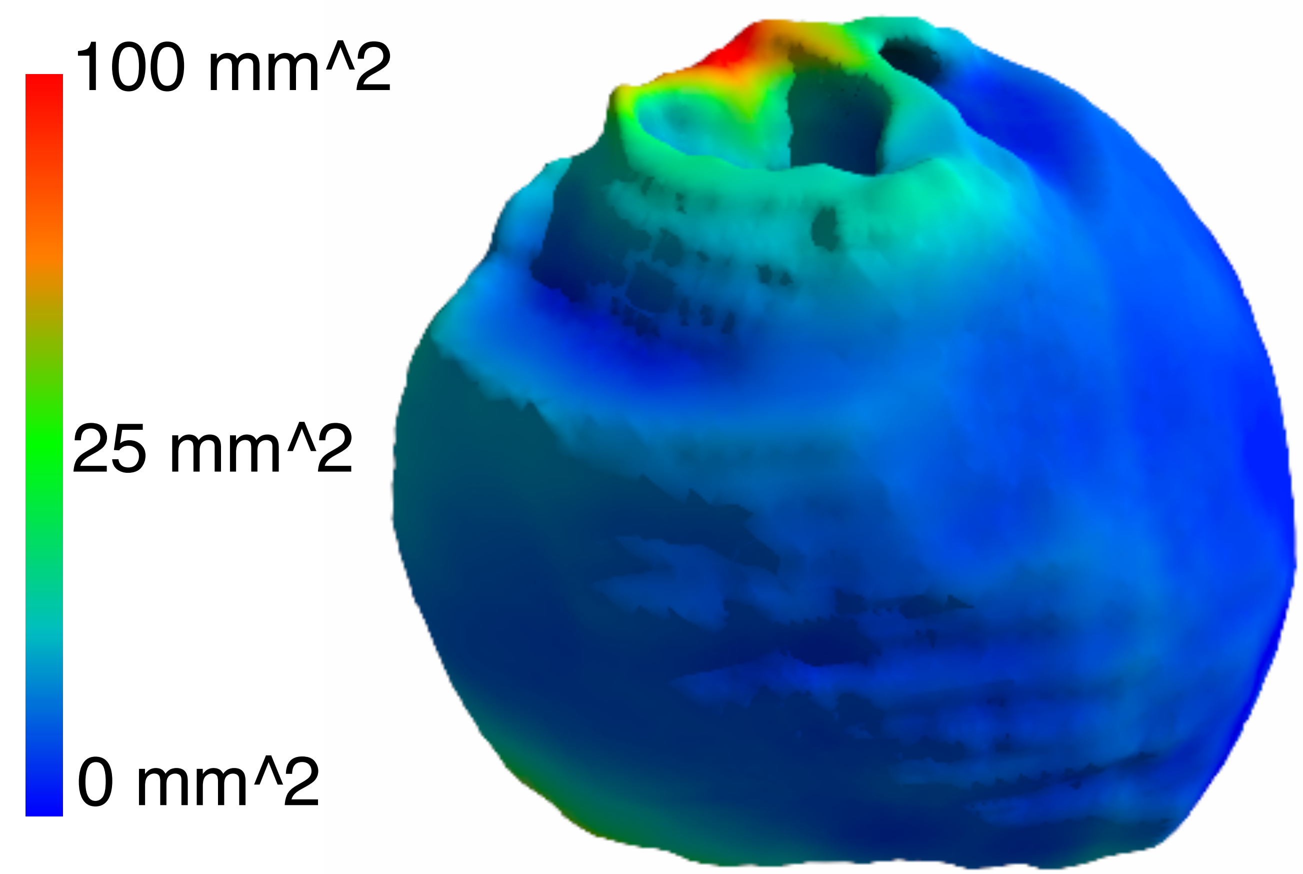


Segmentation Variation



Segmentation Variation





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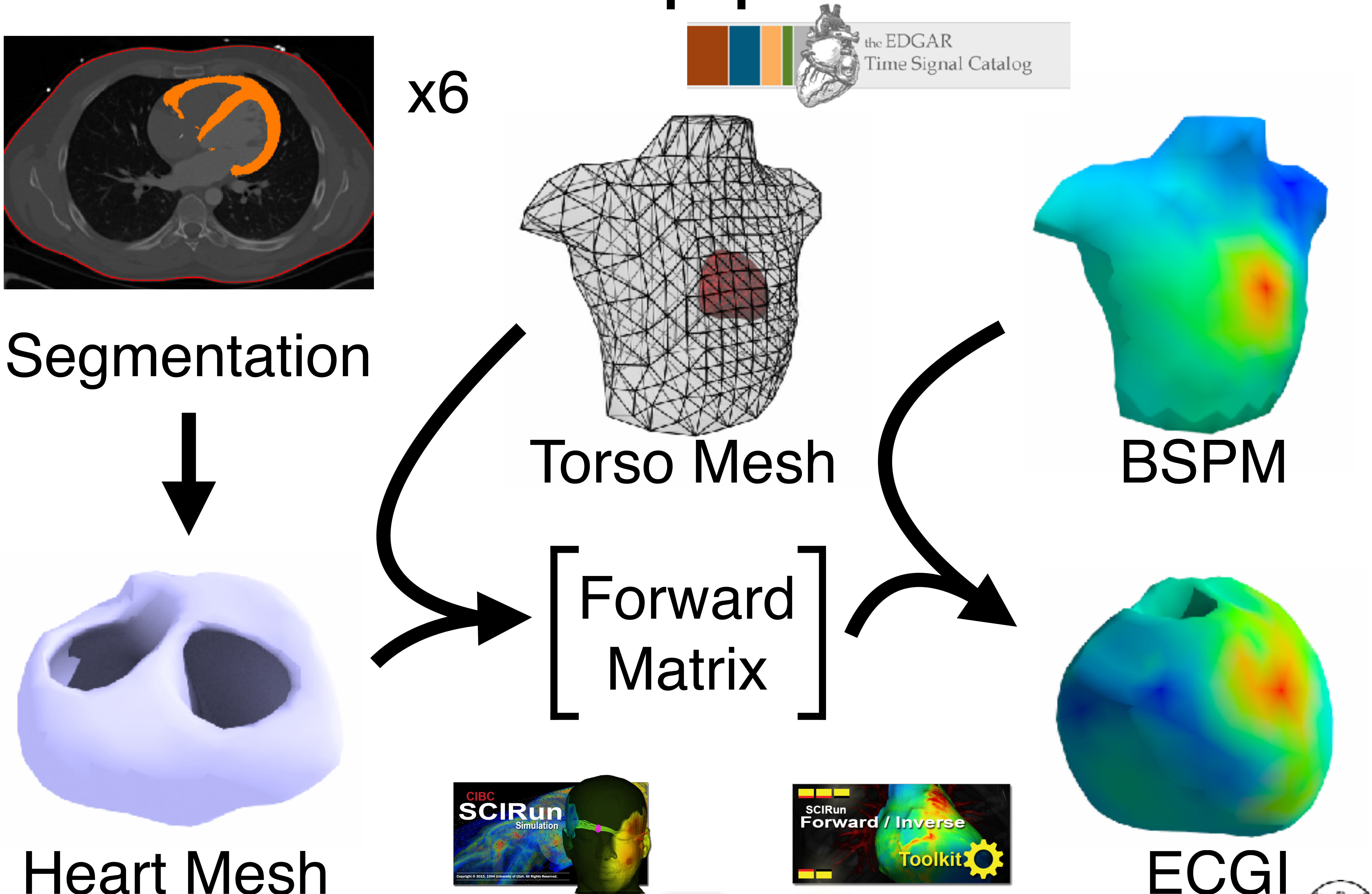
Quantify the effect of segmentation variation on ECGI solutions

ECGI pipeline

Covalic

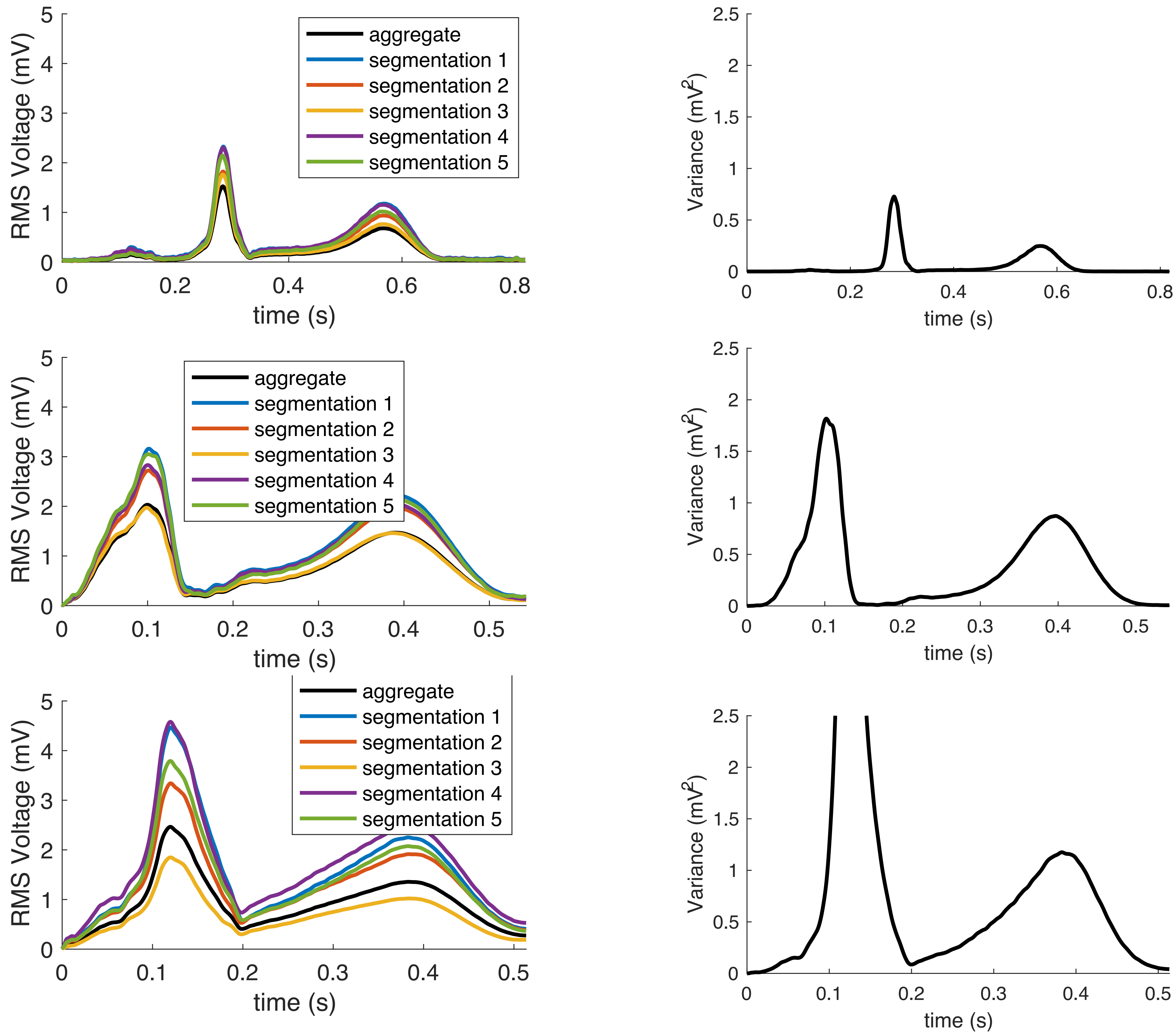


Variance Over Time

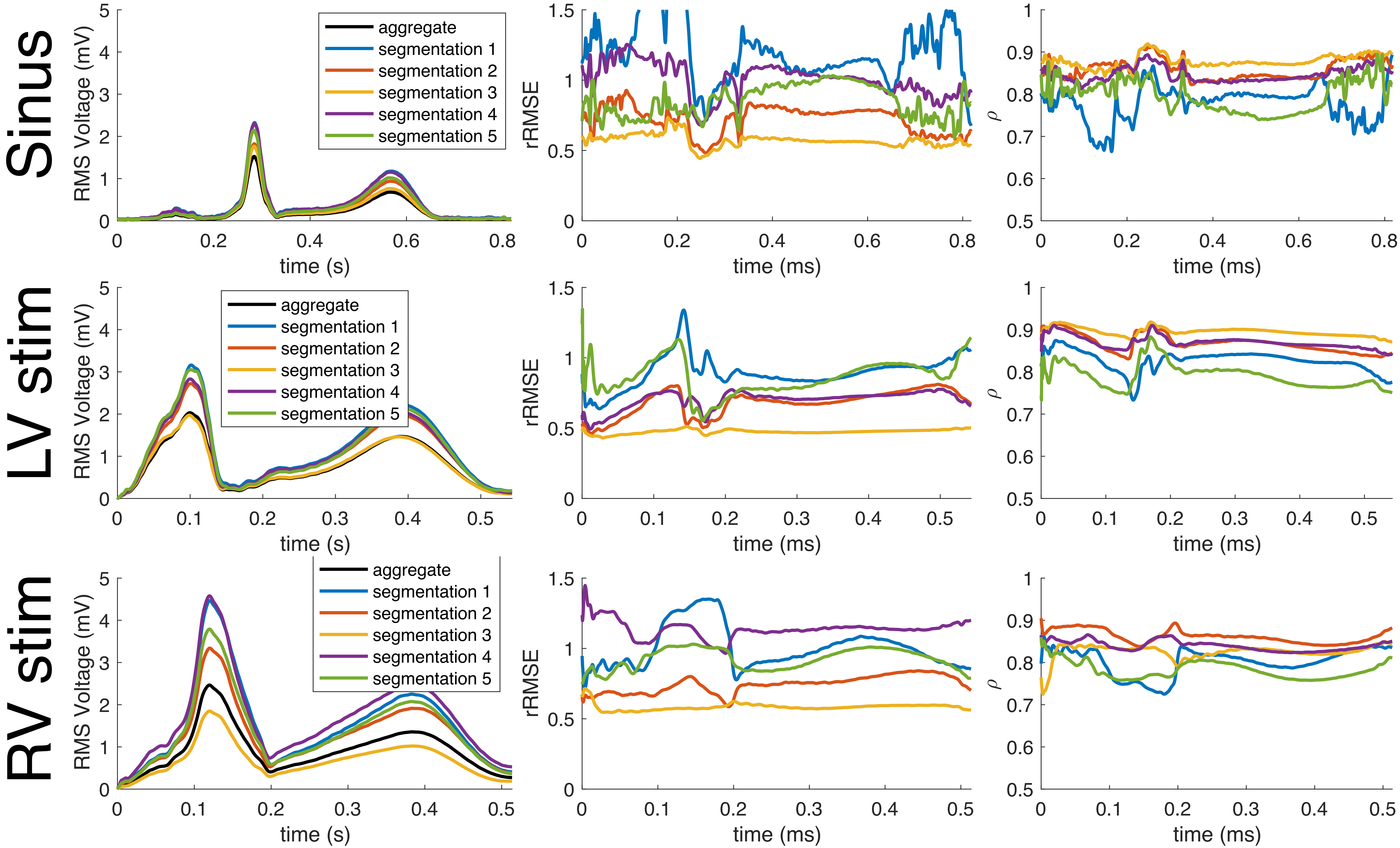
Sinus

LV stim

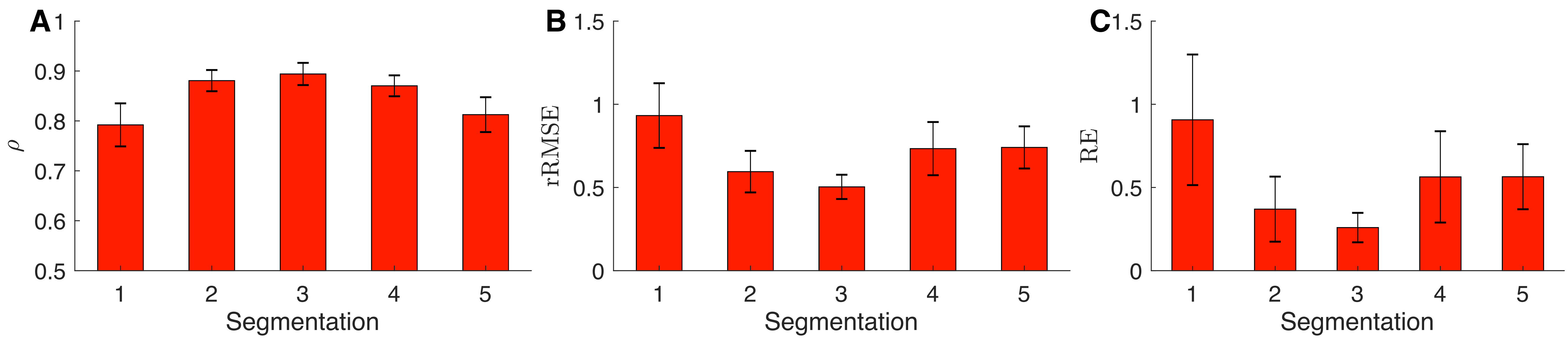
RV stim



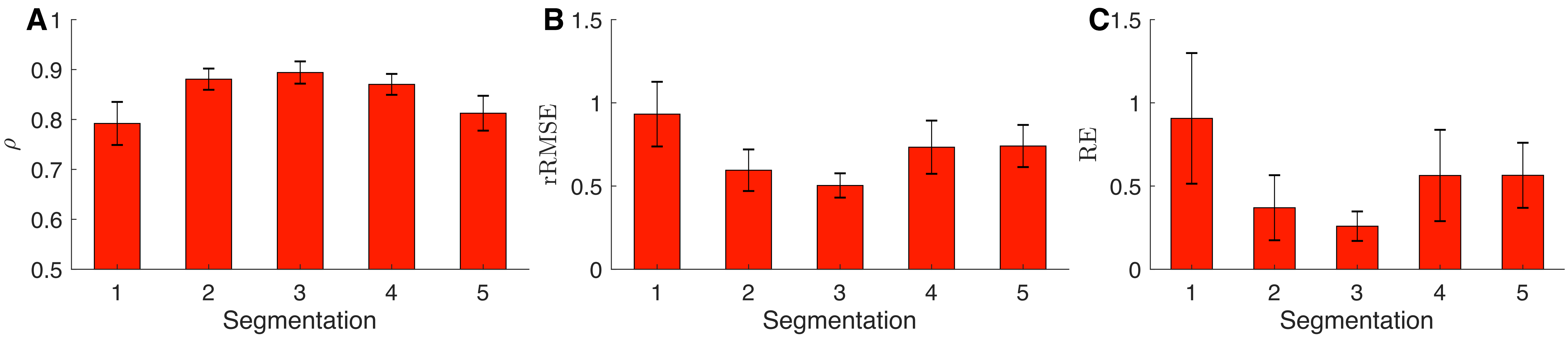
Variation Over Time

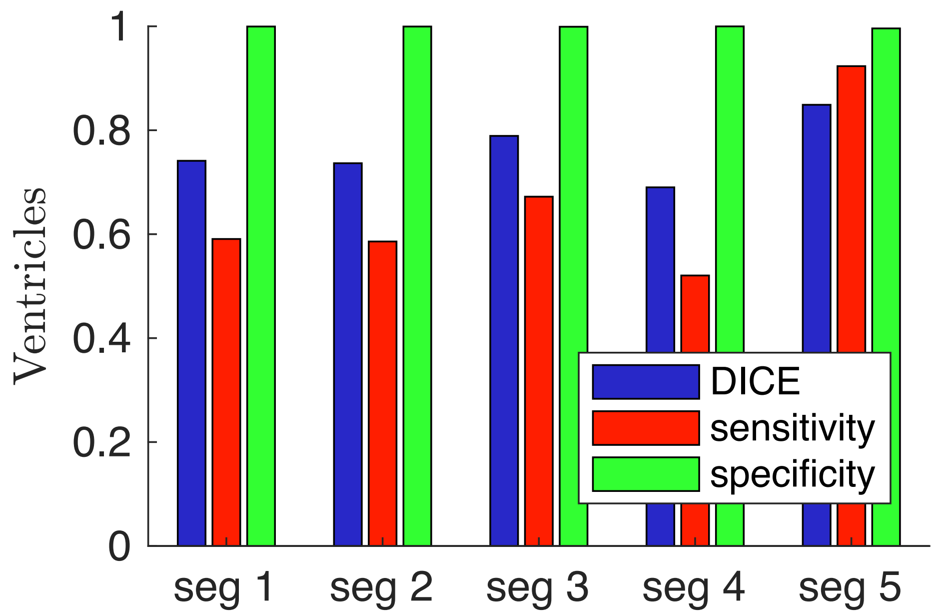


Total Error

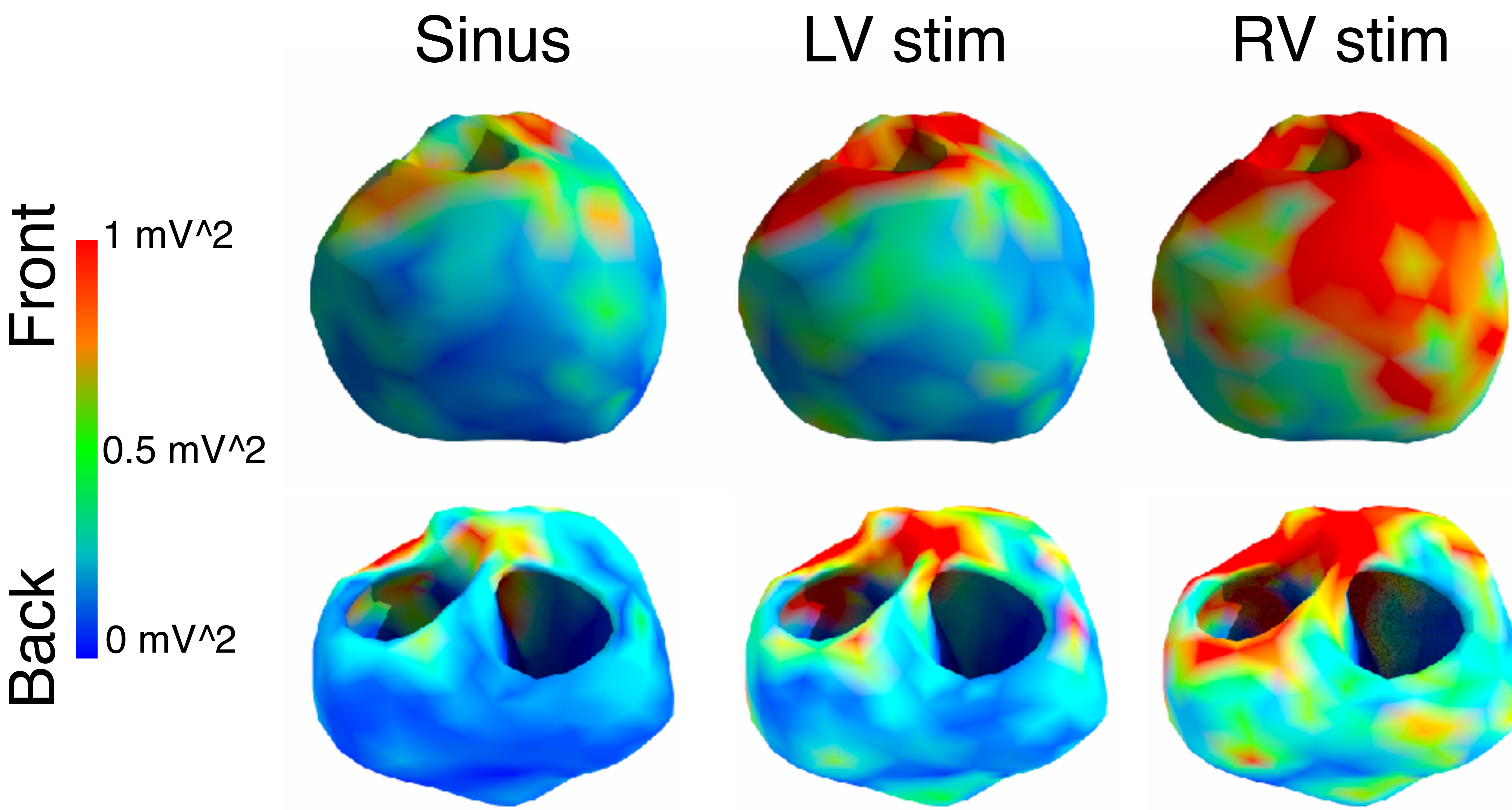

A
B
C
ρ
rRMSE
RE
1
0.9
0.8
0.7
0.6
0.5
1.5
0.5
0
1 2 3 4 5
Segmentation
Segmentation
Segmentation

Total Error


A
B
C
ρ
rRMSE
RE
Segmentation
Segmentation
Segmentation


Ventricles
DICE
sensitivity
specificity
seg 1
seg 2
seg 3
seg 4
seg 5

Locations of High Variance



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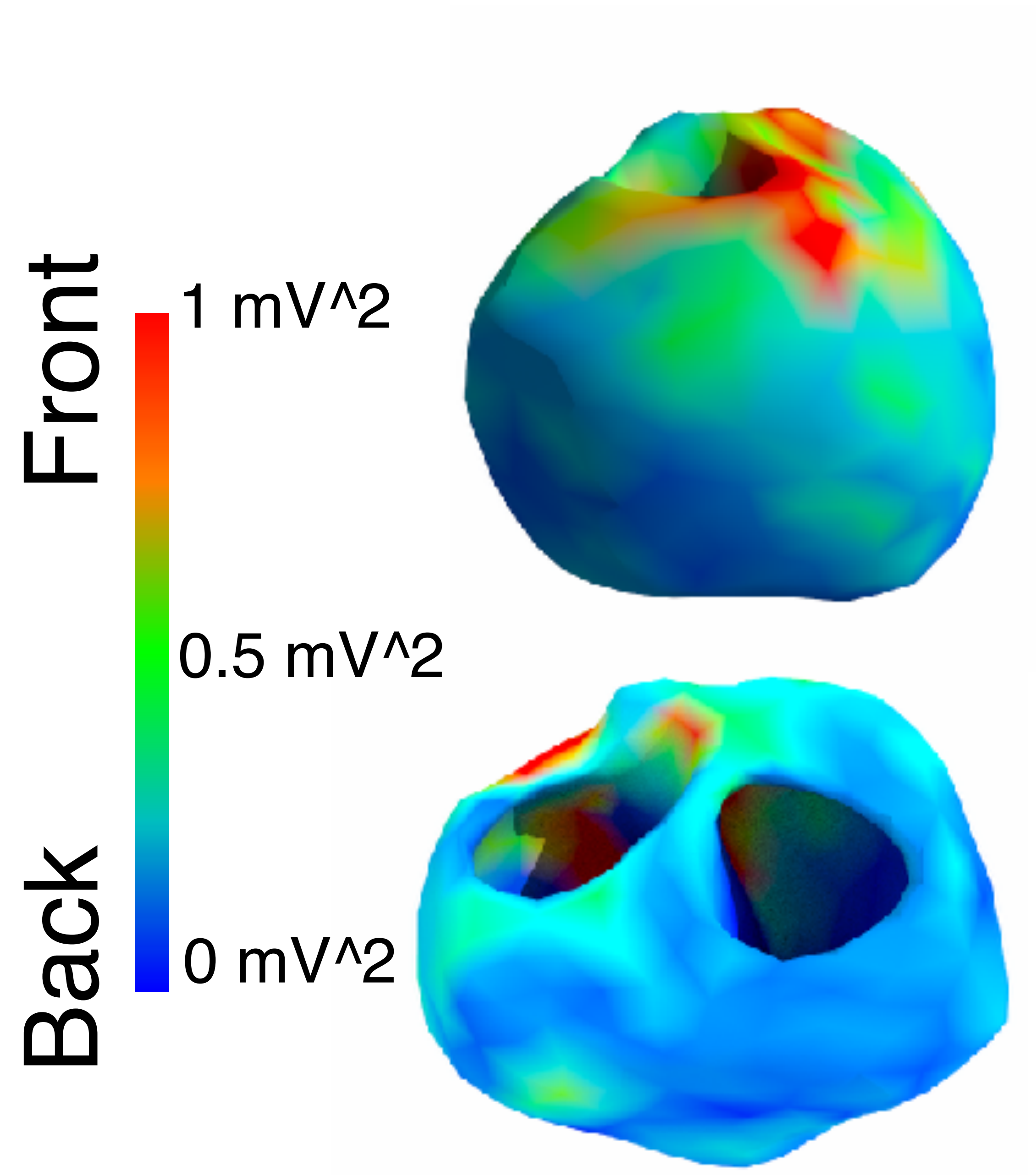
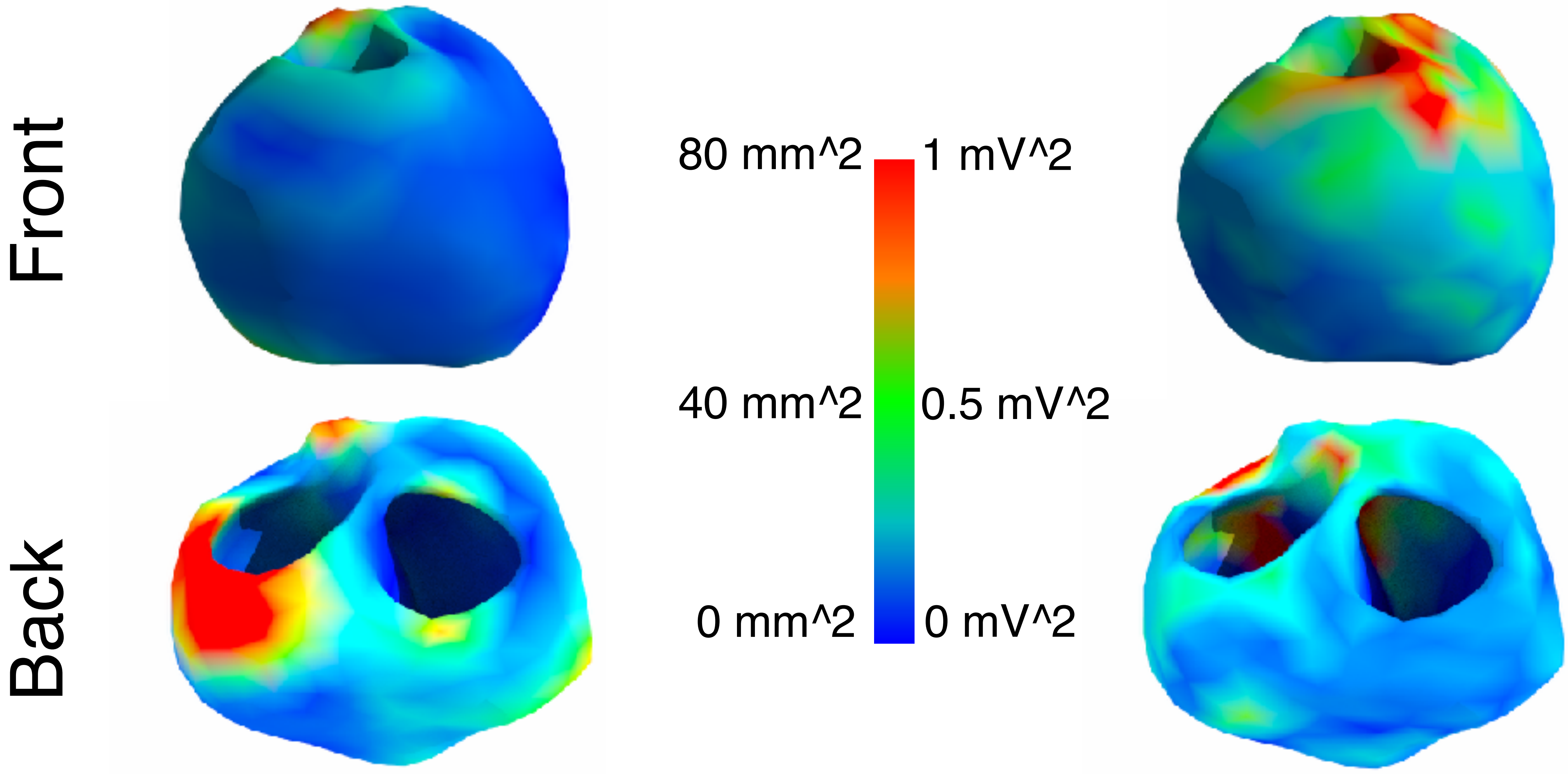
Variance of Solutions and Meshes



Solution Variance

Variance of Solutions and Meshes



Mesh Variance

Solution Variance

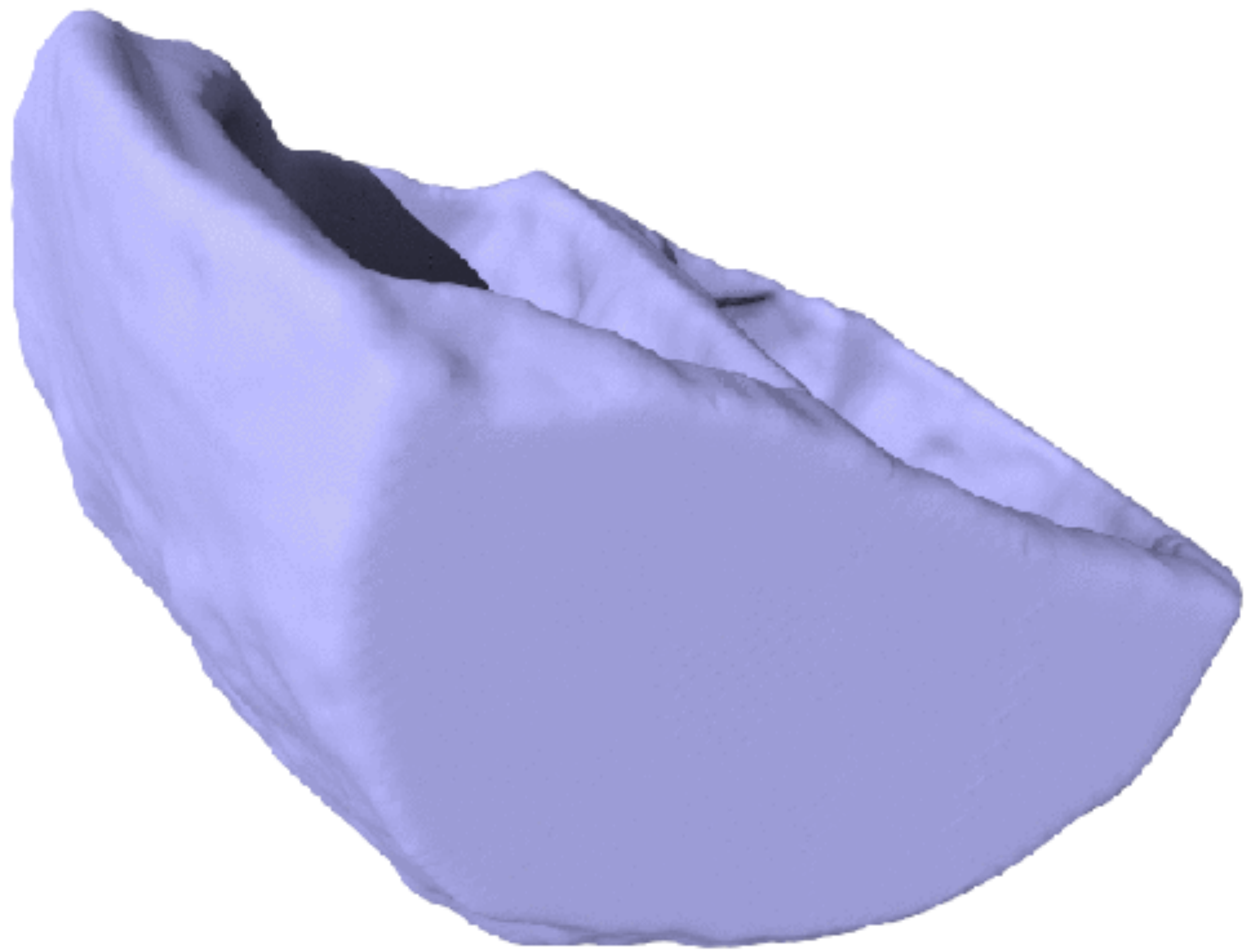
ECGI can be sensitive to segmentation errors

High variance in ECGI solution corresponds to high variance in Segmentation

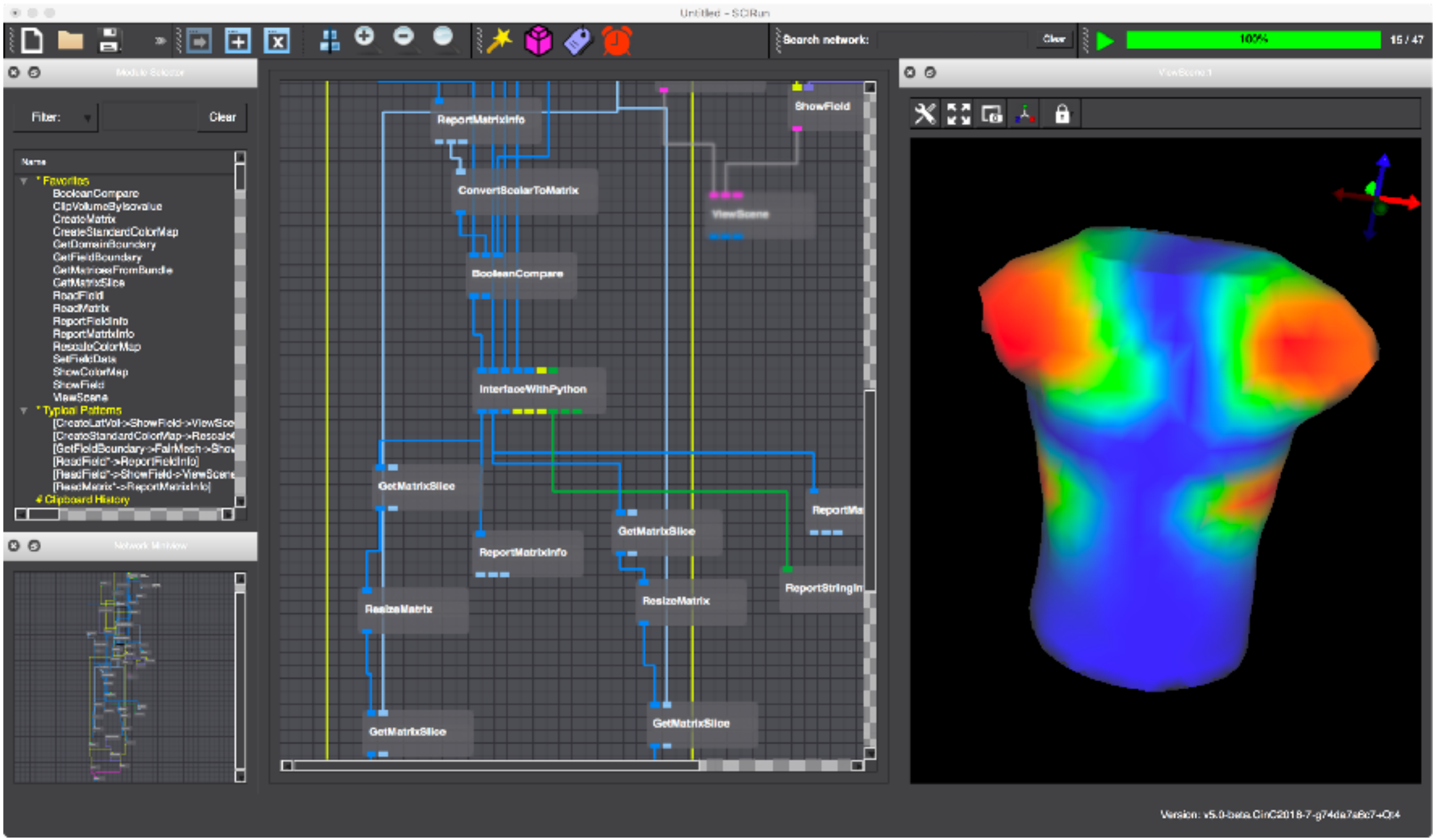
Anterior region is more sensitive to segmentation variation

What's Next?

Shape Analysis



Uncertainty Quantification



Communicating accuracy of ECG and ECGI

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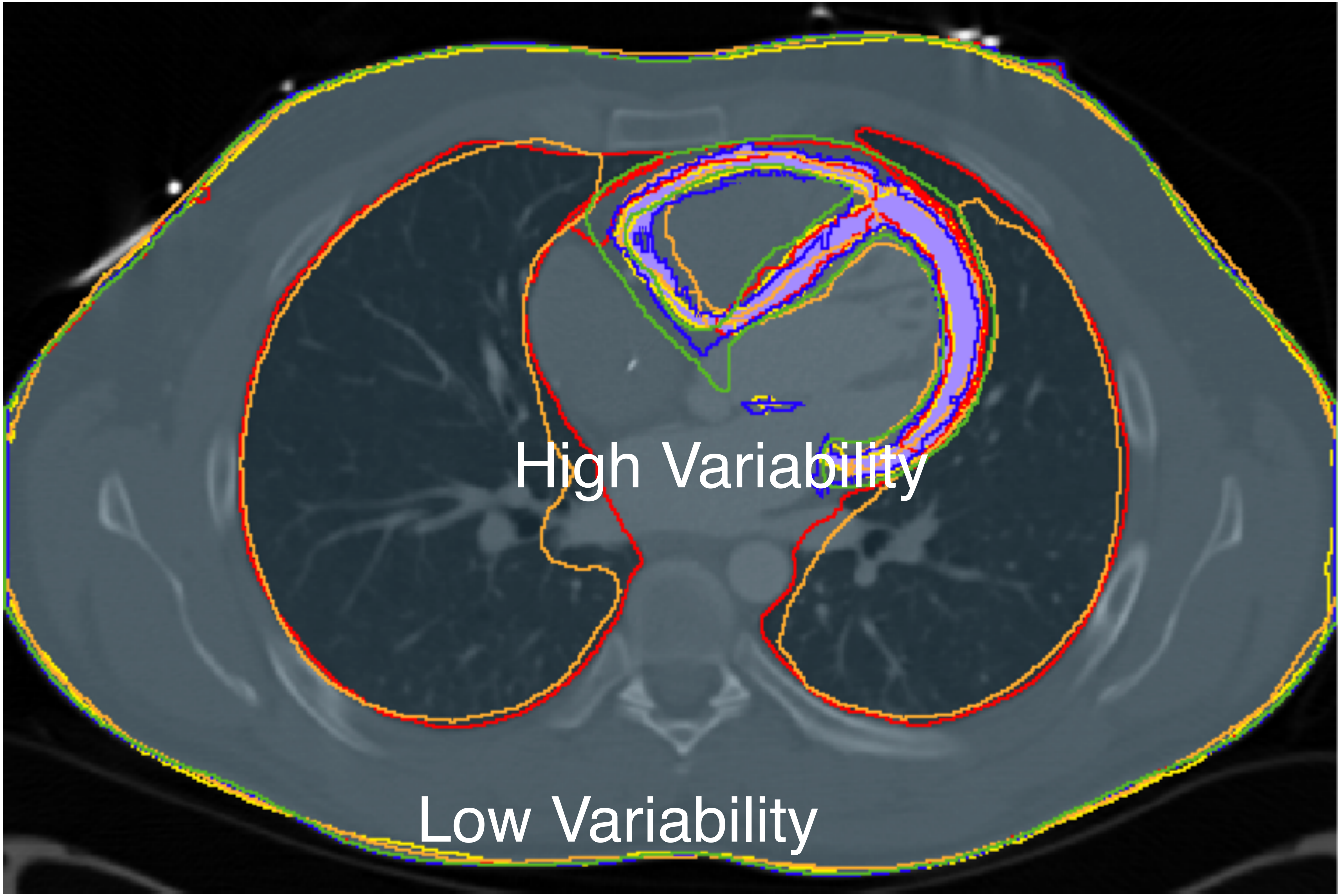
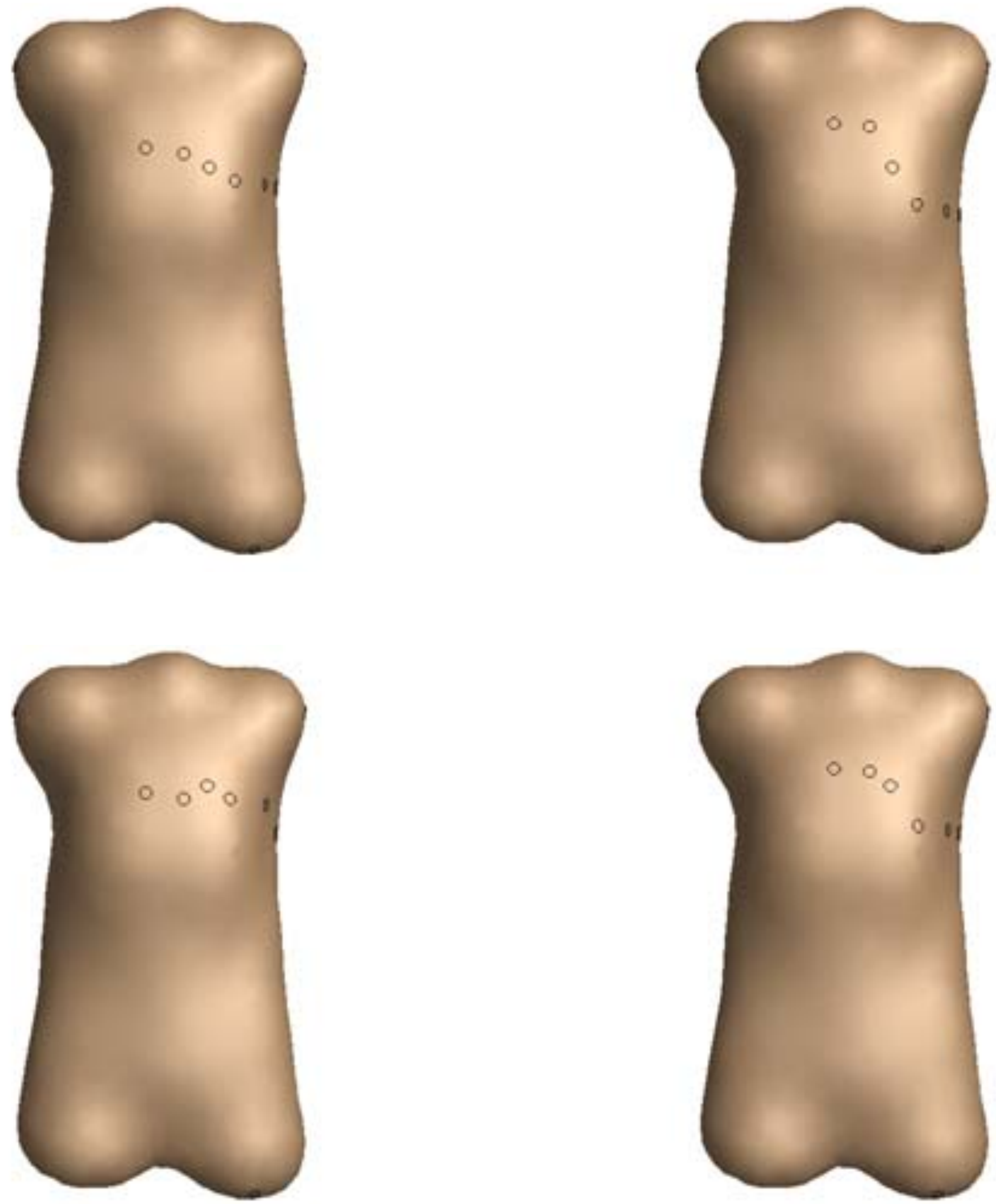
Torso Variability?



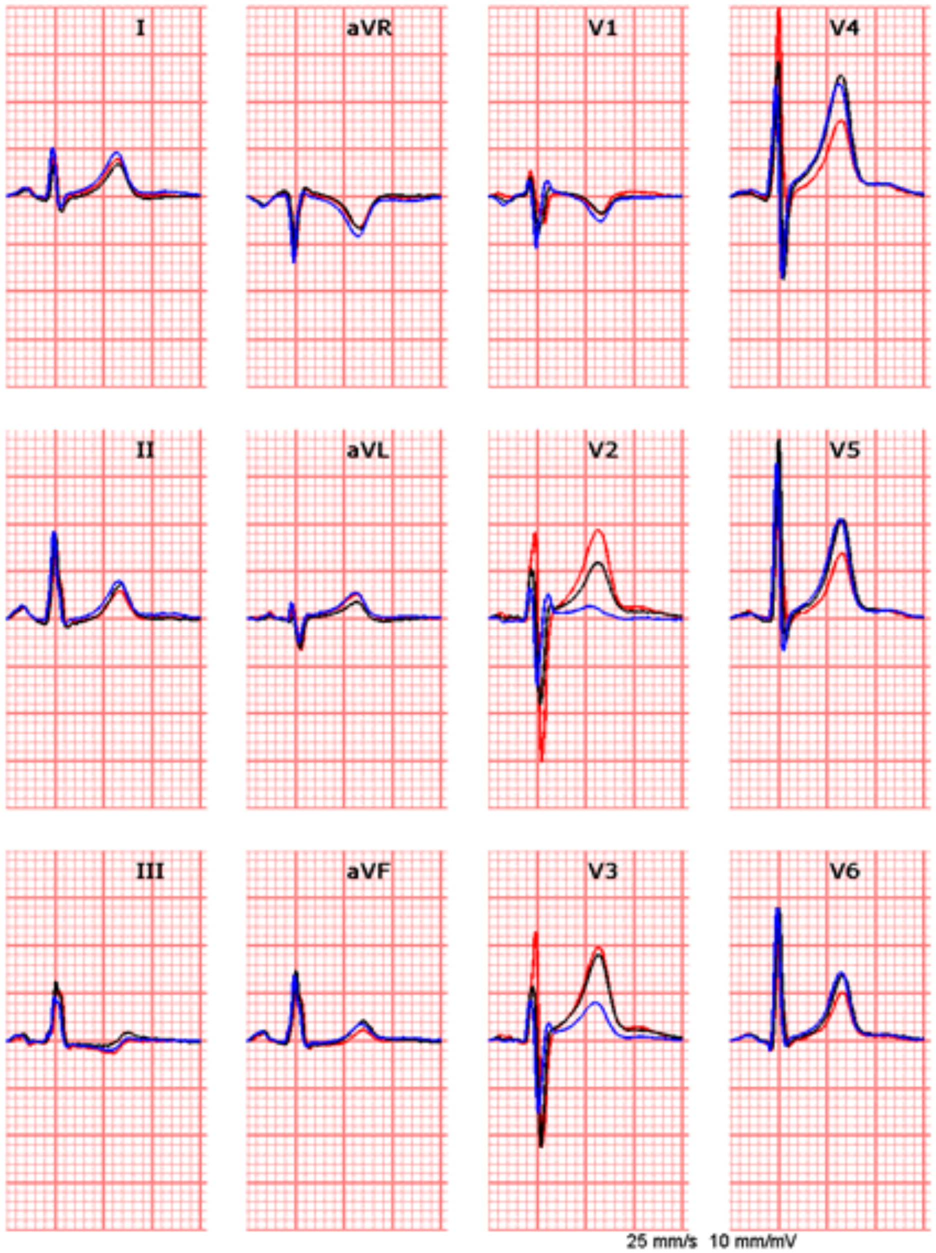
Electrode Variability



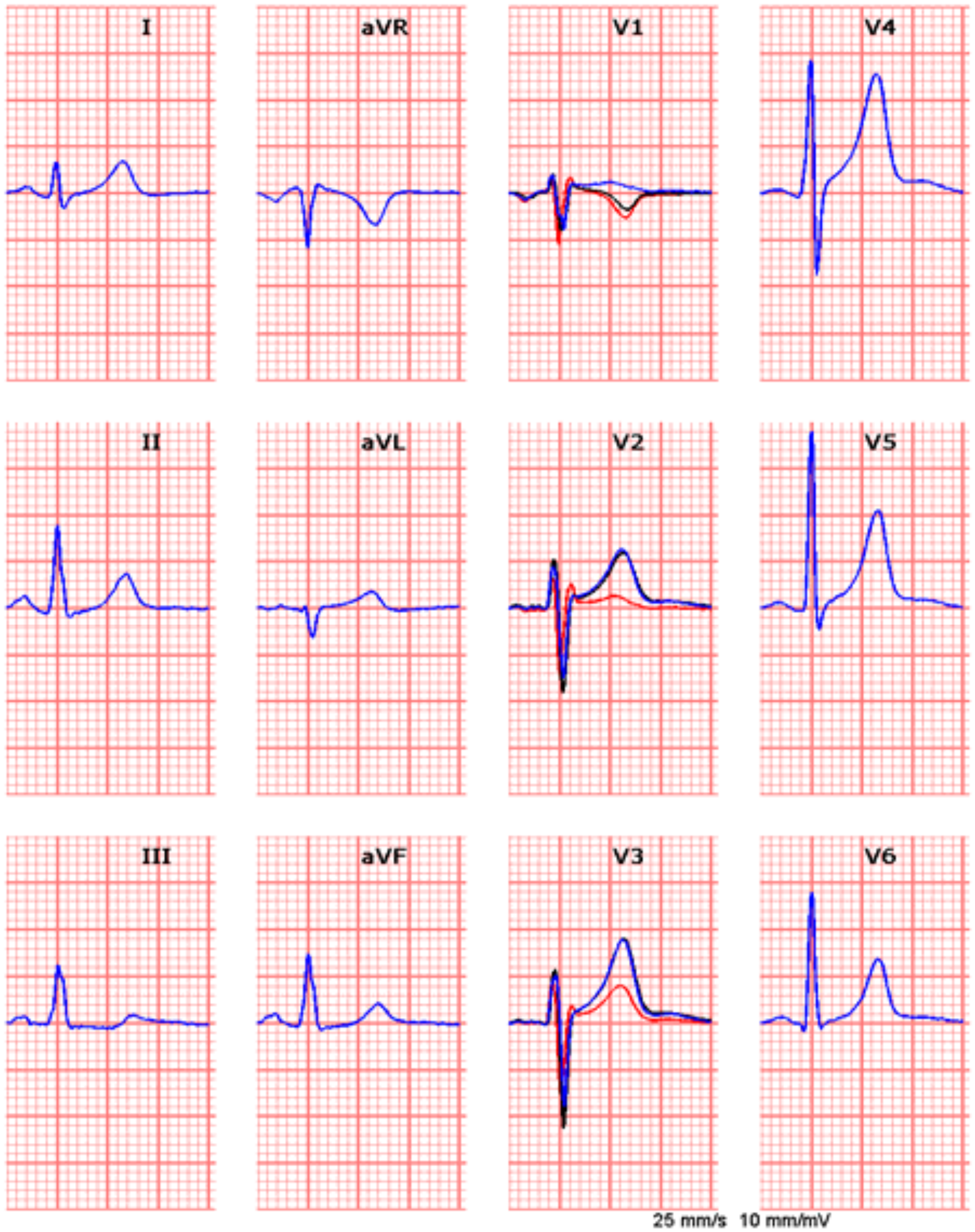
Misplaced Leadsets

van Dam, etal. Computing in Cardiology 2013; 40:1175-1178

Electrode Variability



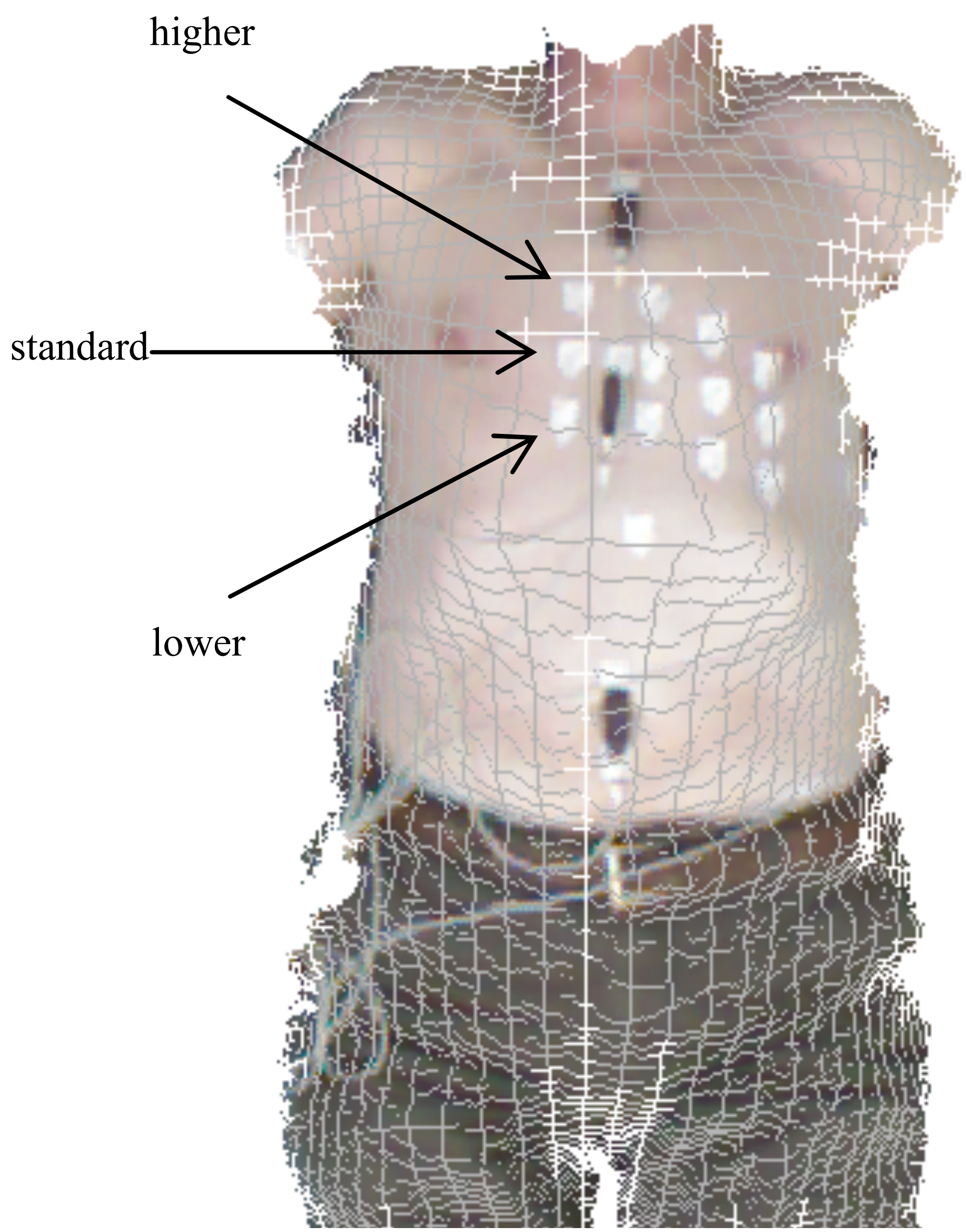
Misplaced Precordial Electrodes



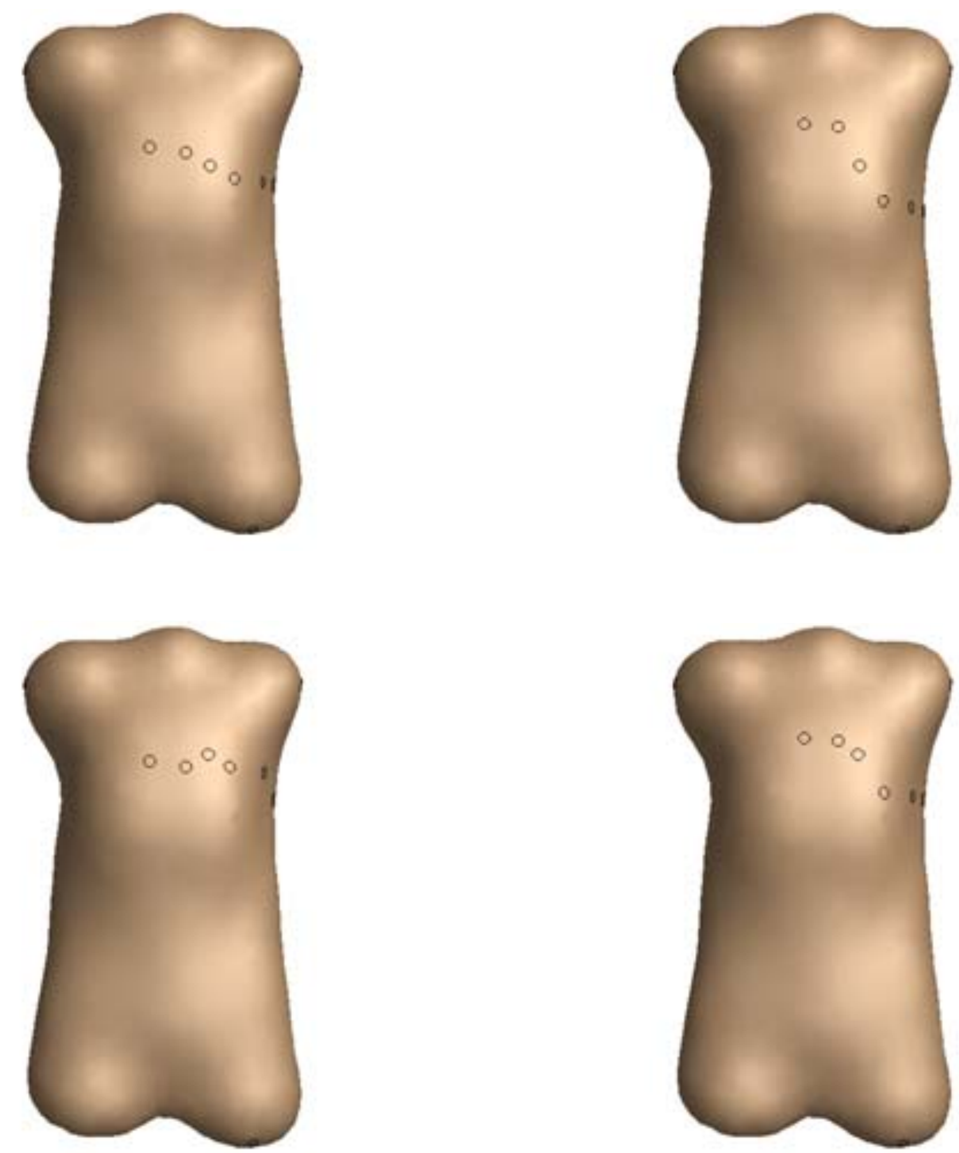
Misplaced Reference Electrodes

van Dam, etal. Computing in Cardiology 2013; 40:1175-1178

Electrode Variability



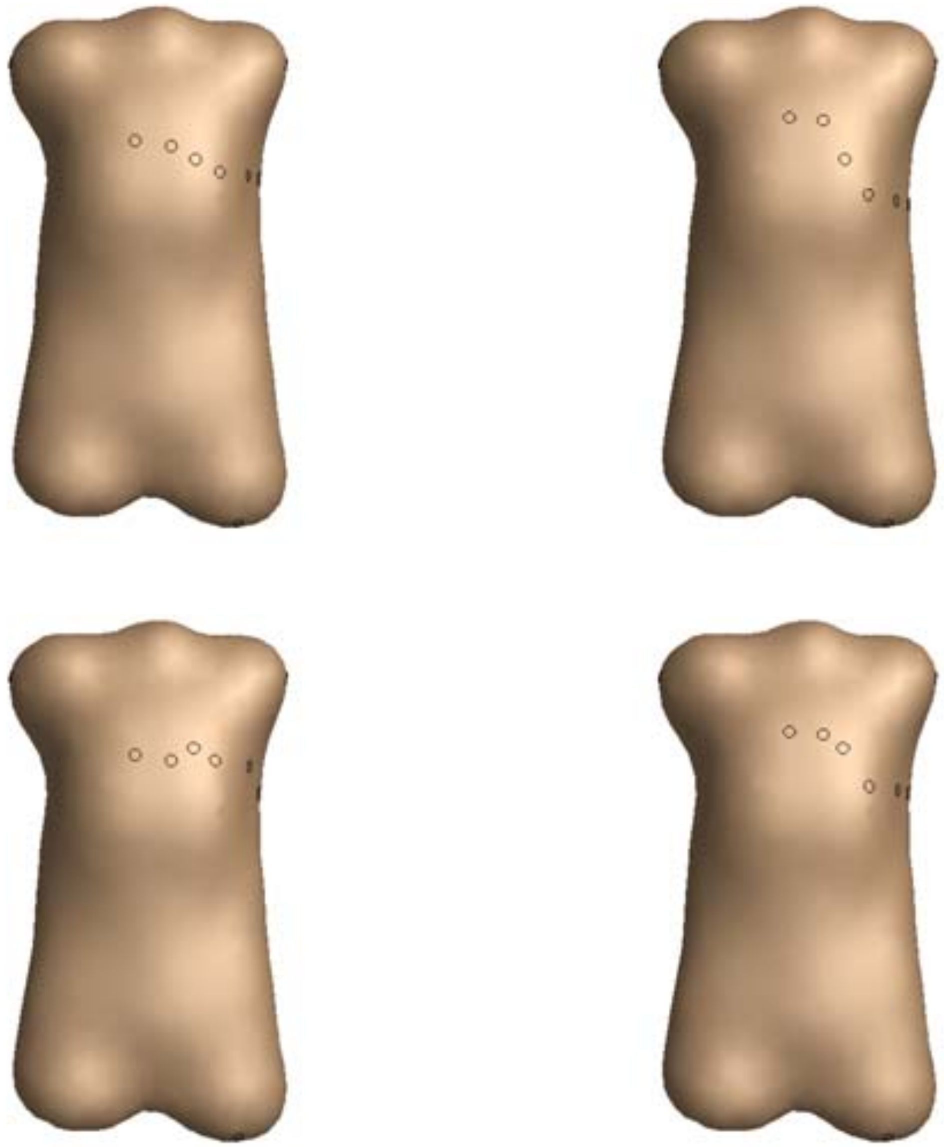
Infrared Camera



Patient-Specific Positions

van Dam, etal. Computing in Cardiology 2013; 40:1175-1178

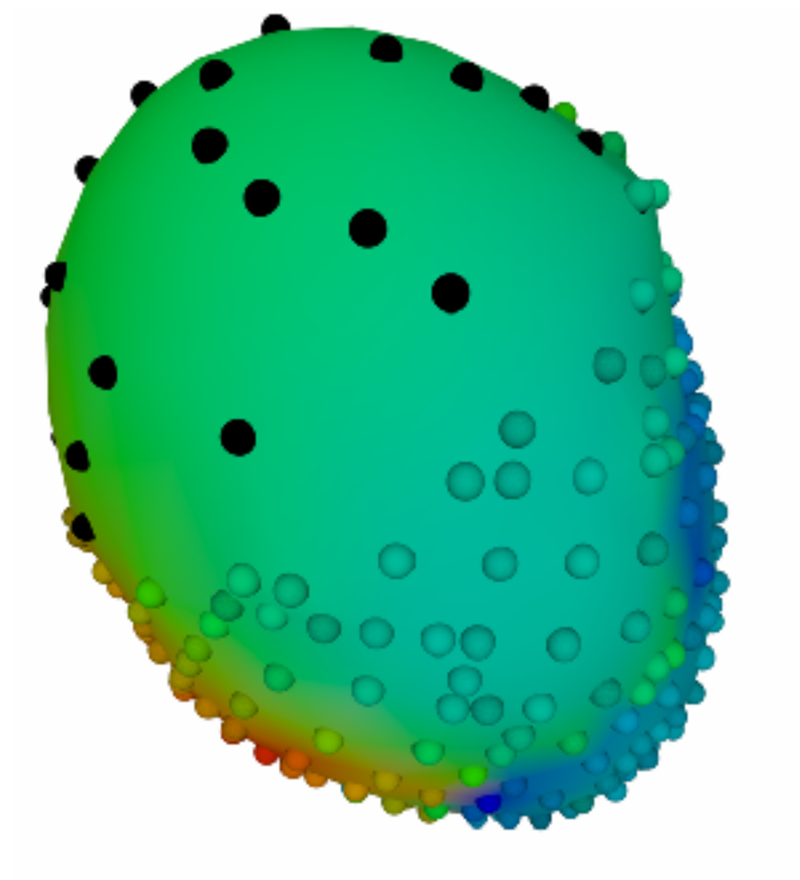
Cardiac Source Geometry?



Electrode Location

Cardiac Surface

Cardiac Source Electrodes?

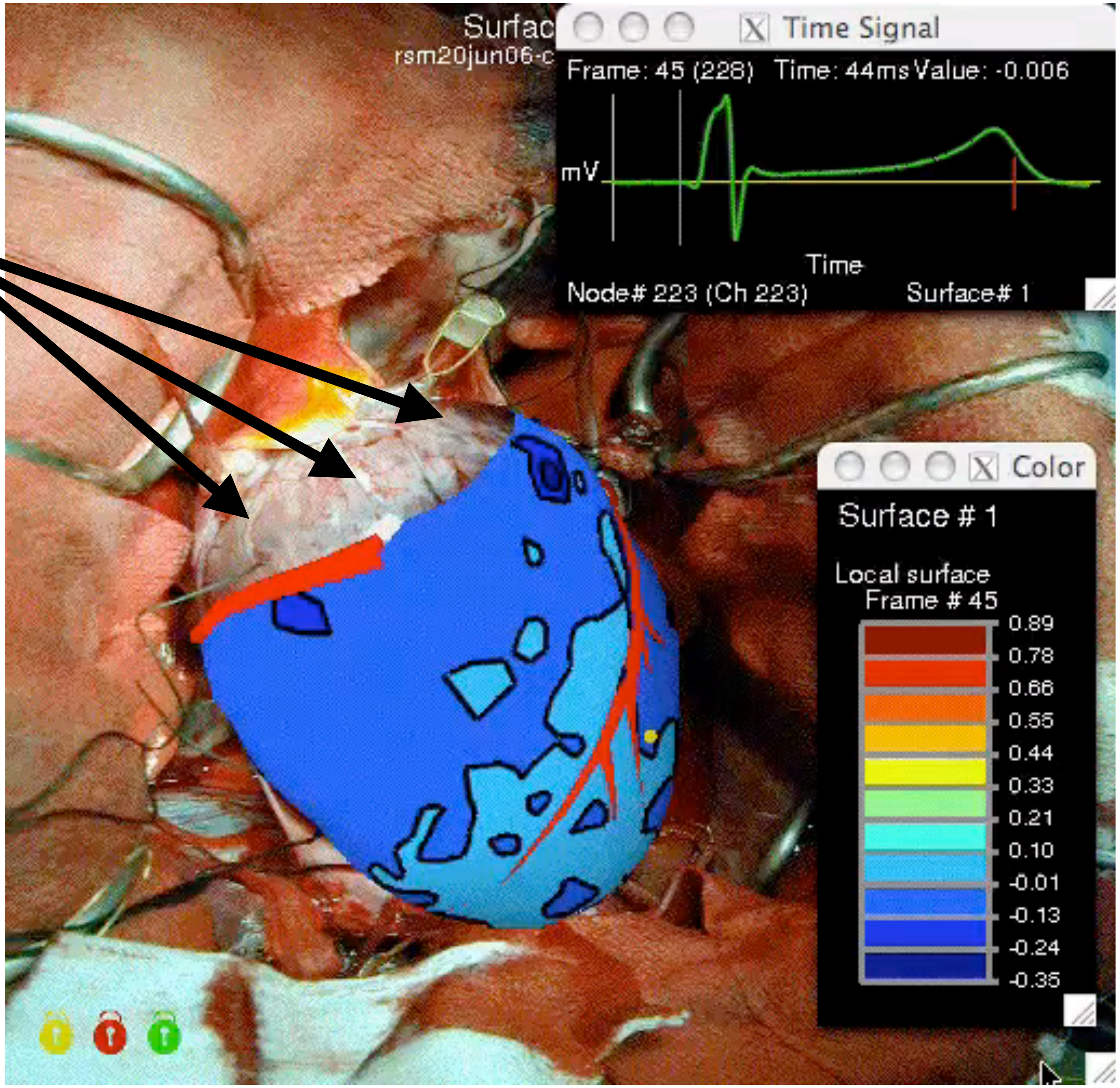


Missing Coverage?
Undersampled?

Effect of Missing Source Coverage On ECG Forward Simulation

Source Recording

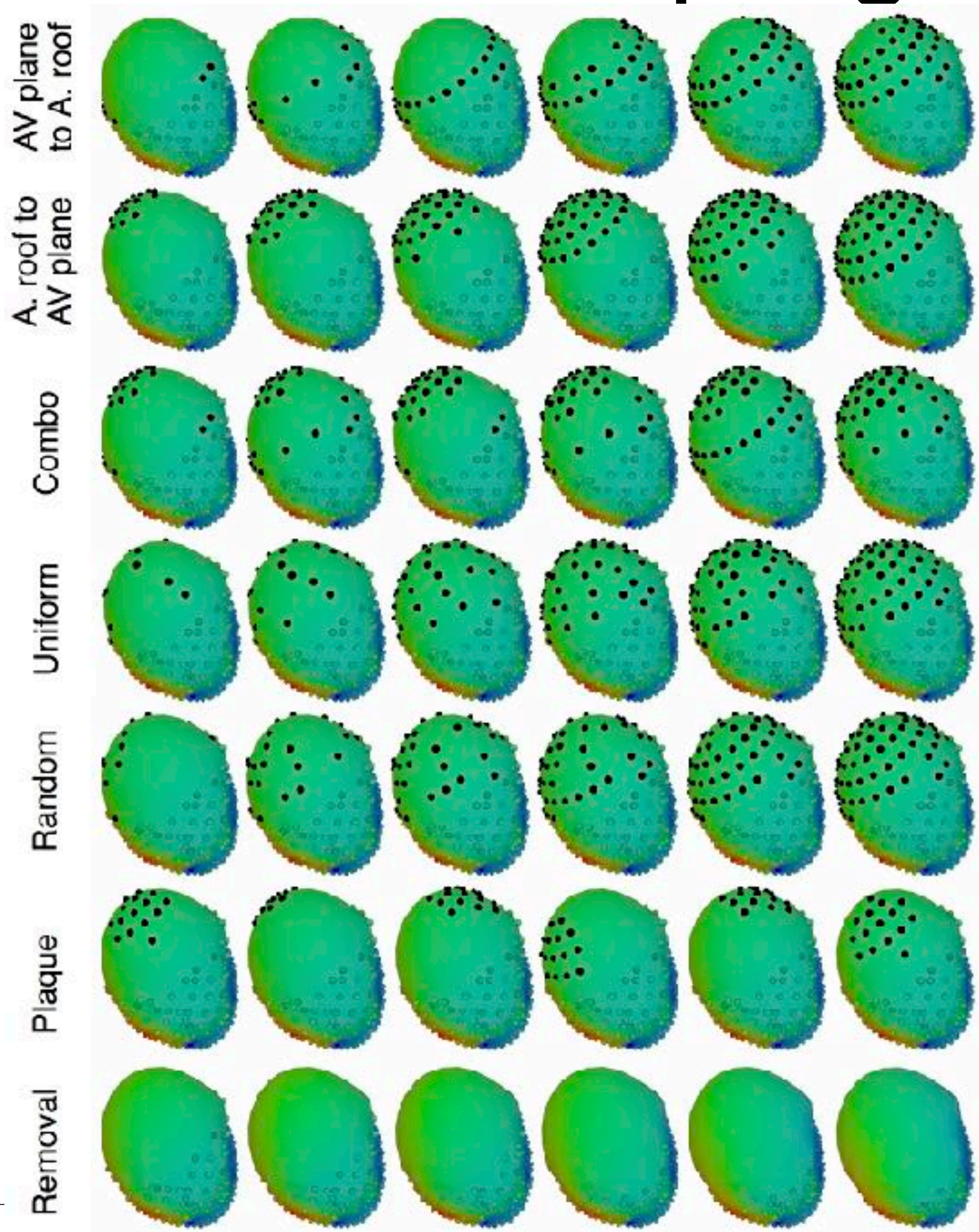
Missing Sources?



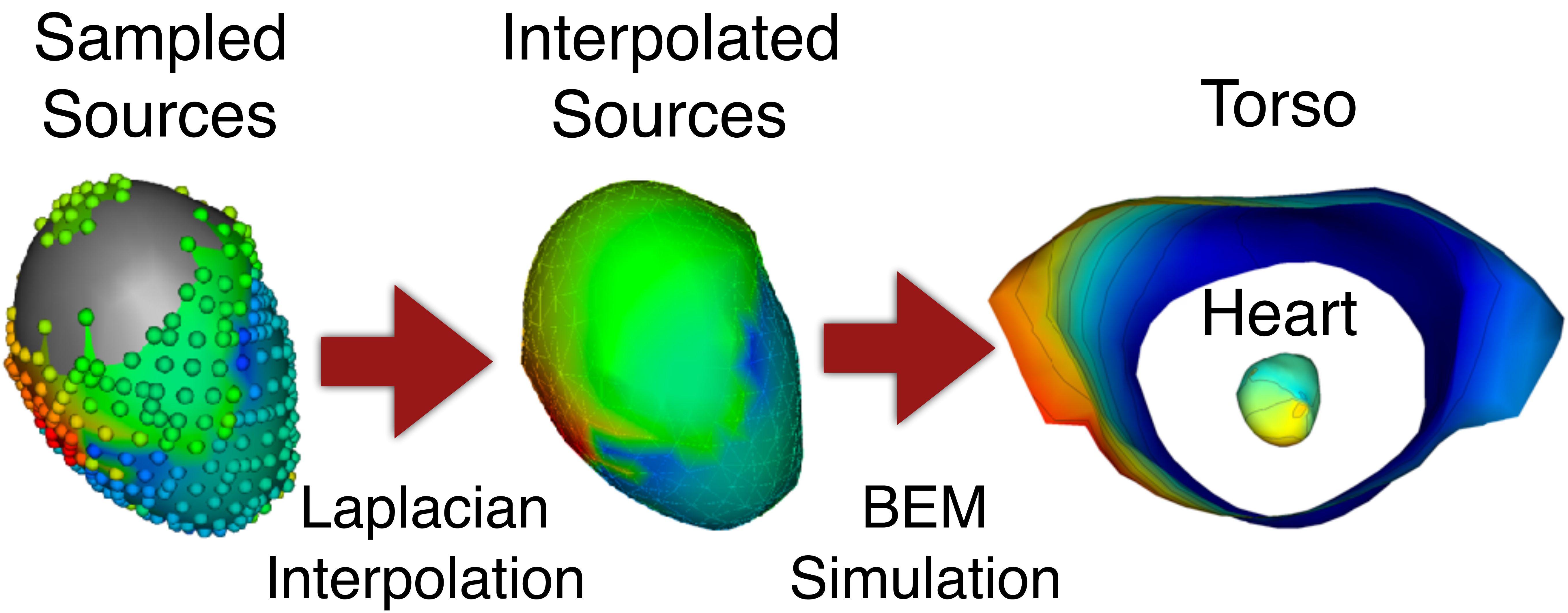
Epicardial Sock
(Ventricle Only)

Test sampling strategies of the atrial region to reduce error in forward simulation

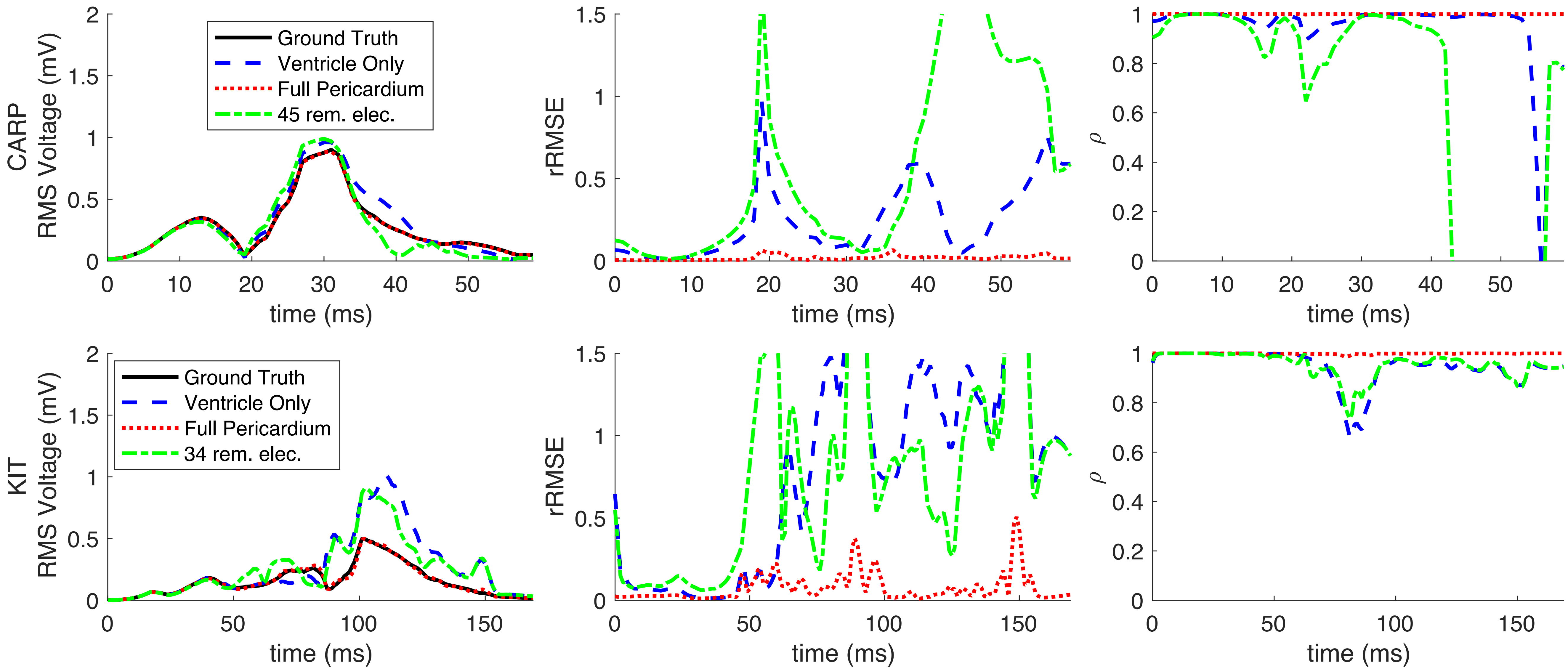
Varied Sampling



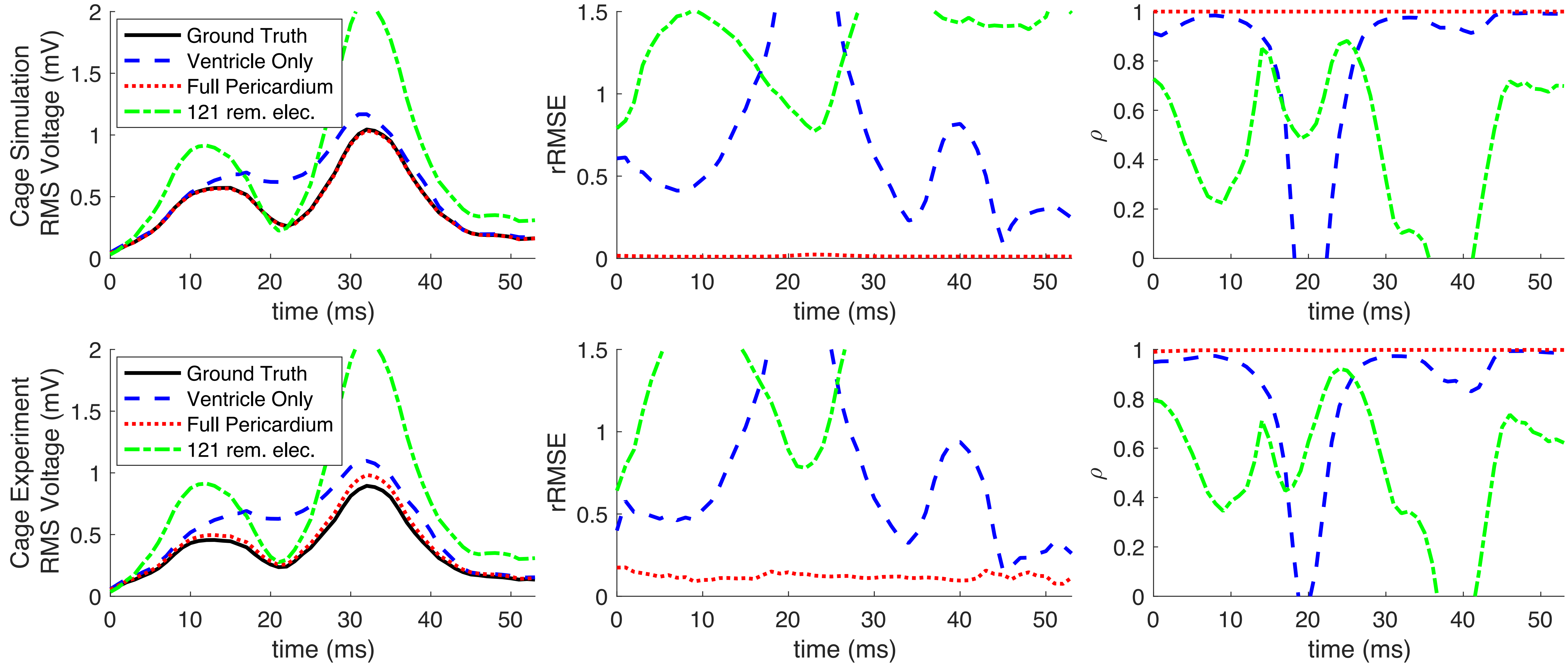
ECG Forward Simulation



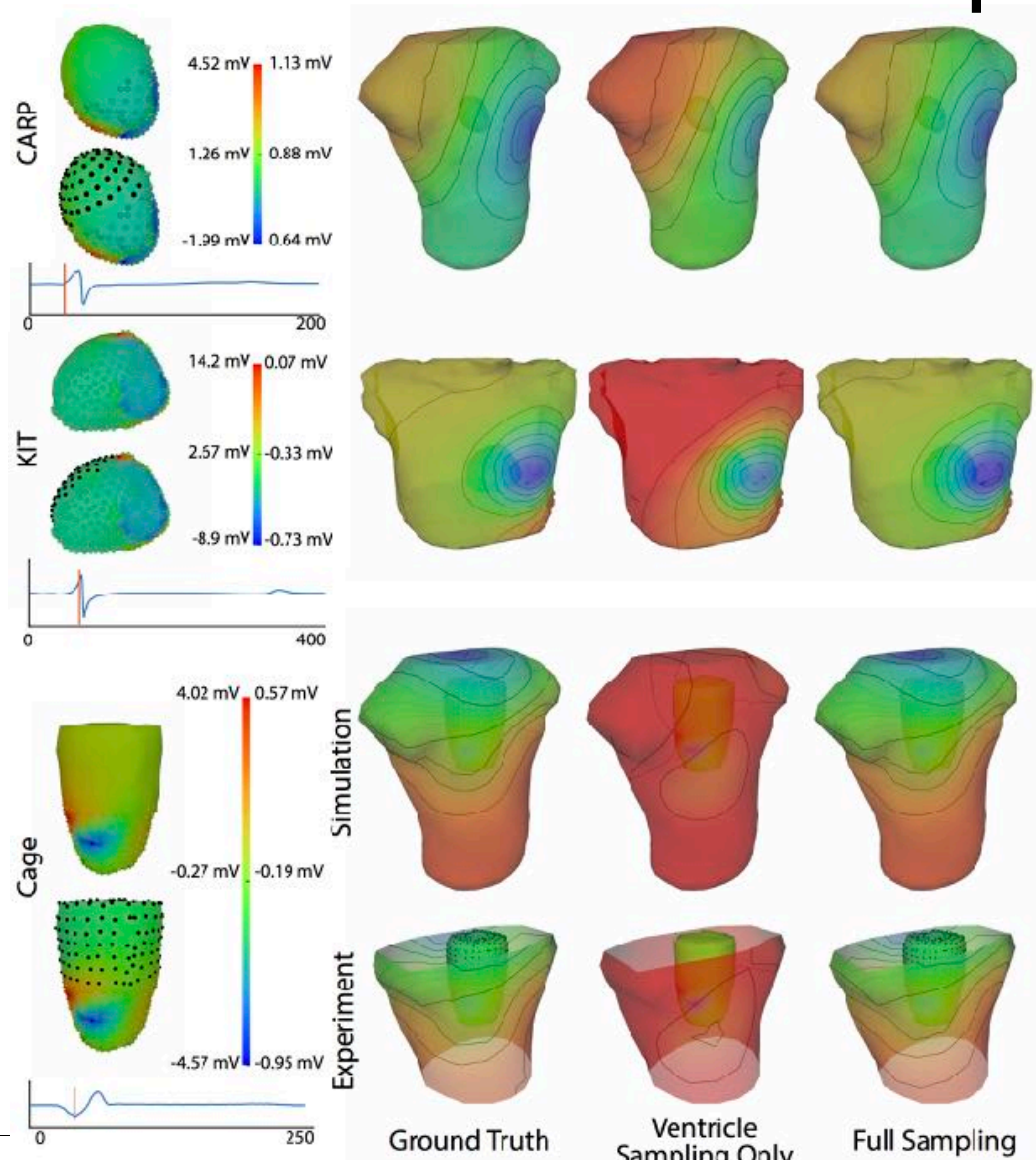
Effect of No Atrial Sampling



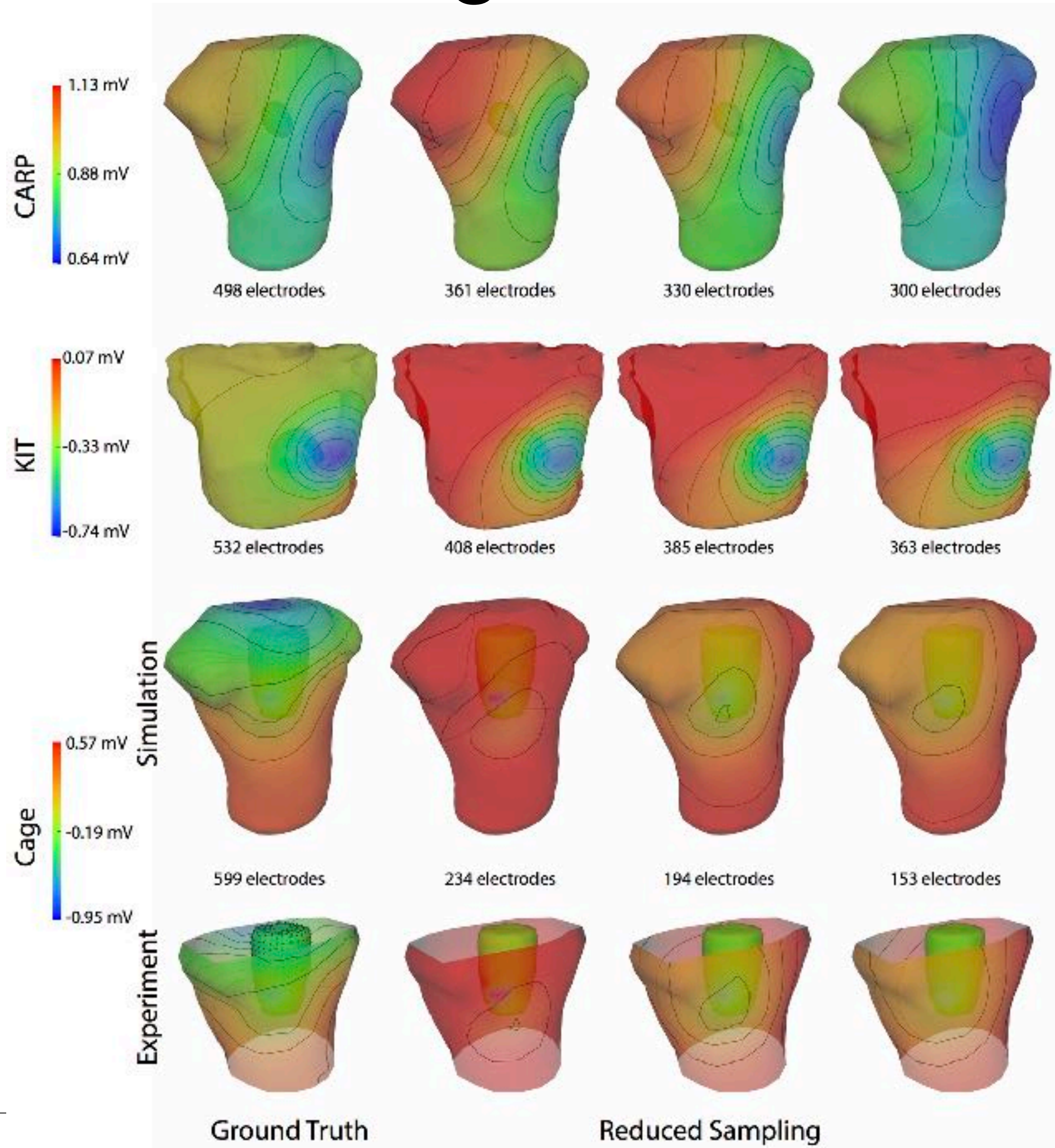
Effect of No Atrial Sampling



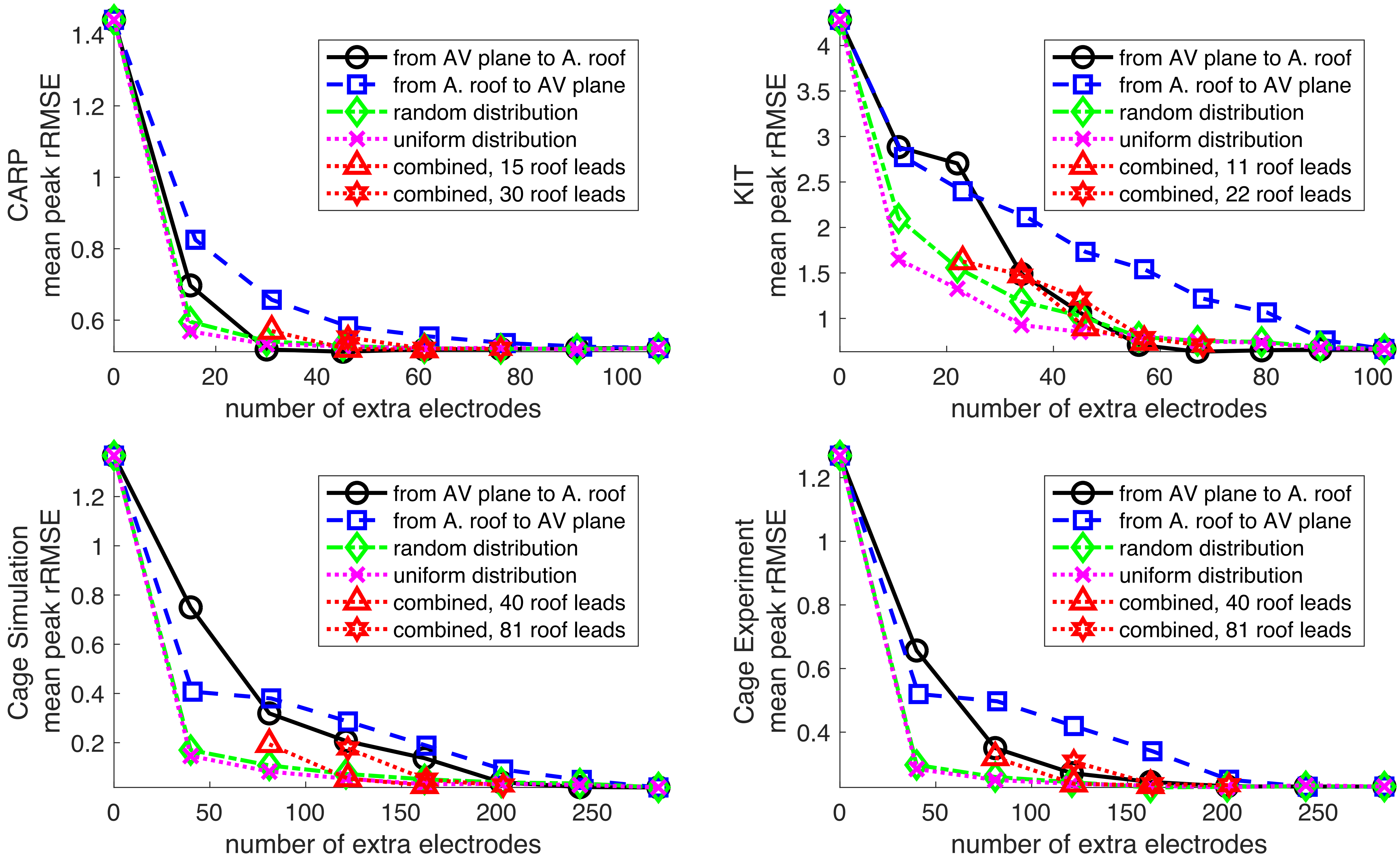
Effect of No Atrial Sampling



Effect of Missing Ventricle Sampling



Progressive Sampling

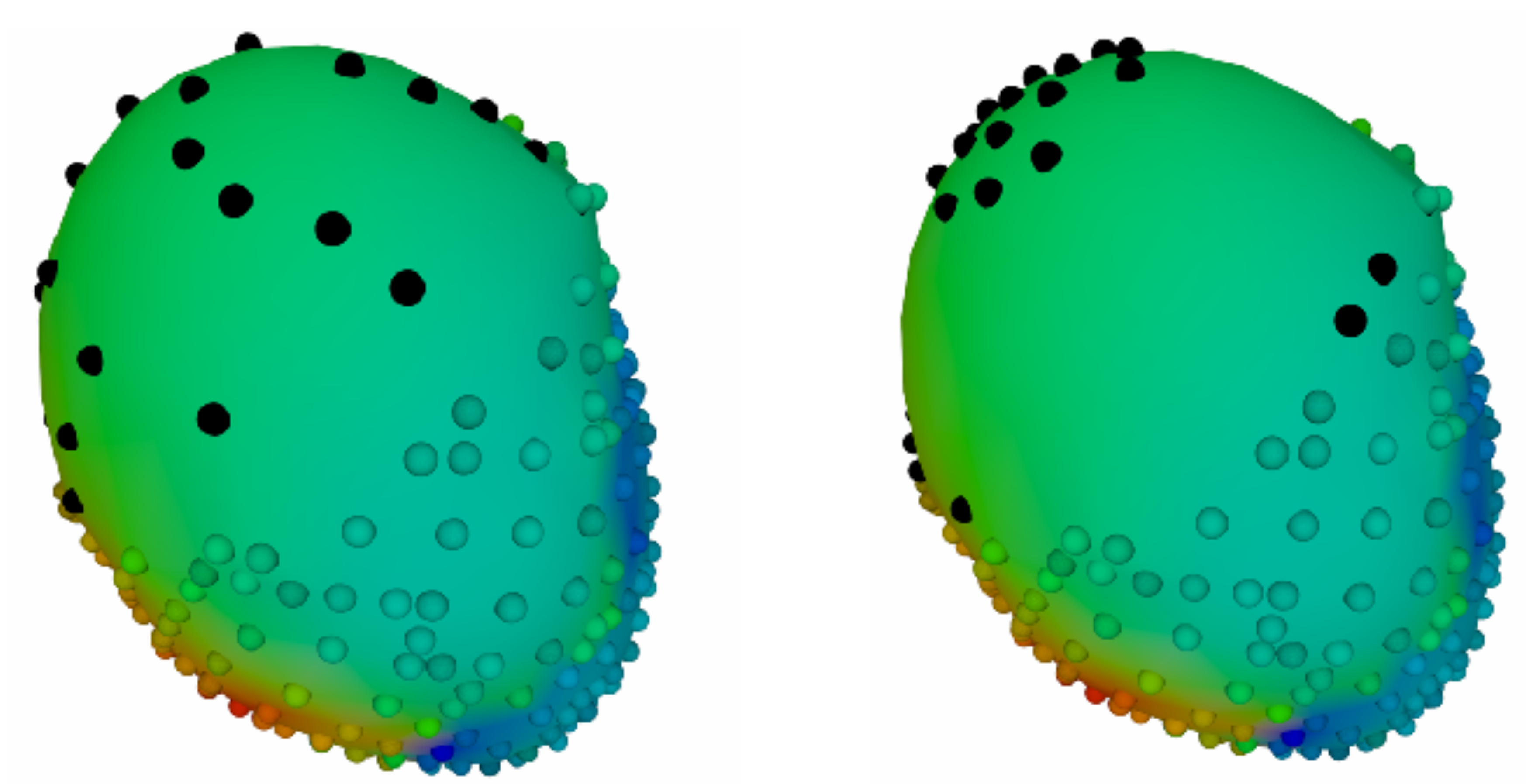


Possible Sampling

More electrodes are better

Sparse placement can reduce error

Missing ventricular sampling increases error further



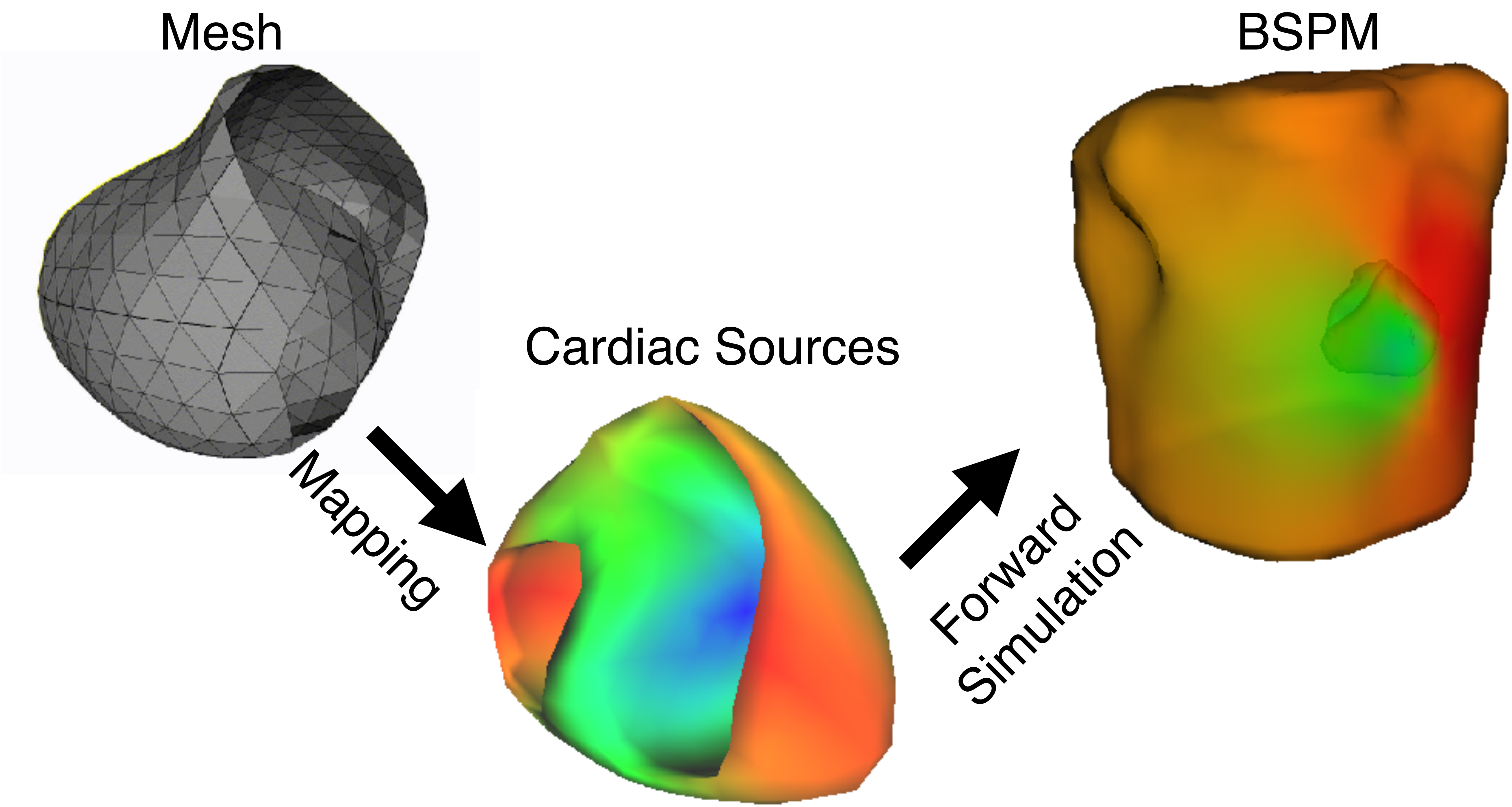
Validation of the ECG Forward Simulation and Subsequent ECGI

Questions:

Errors in the cardiac electrode placement?

Undersampling of the heart?

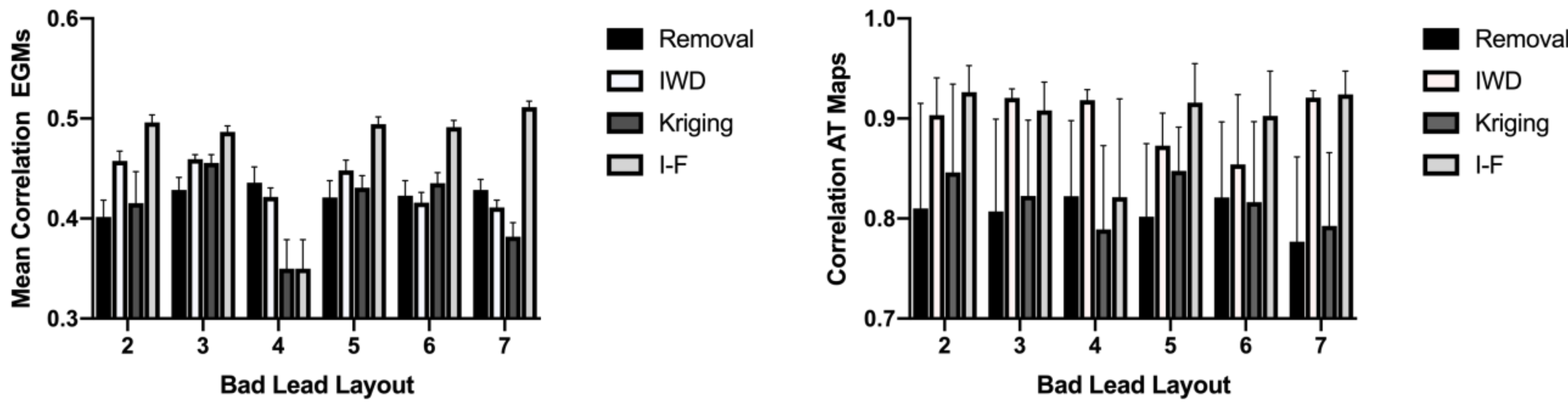
Source Undersampling



Schuler, etal., Tate, etal., FIMH Friday, 16:00

Interpolation

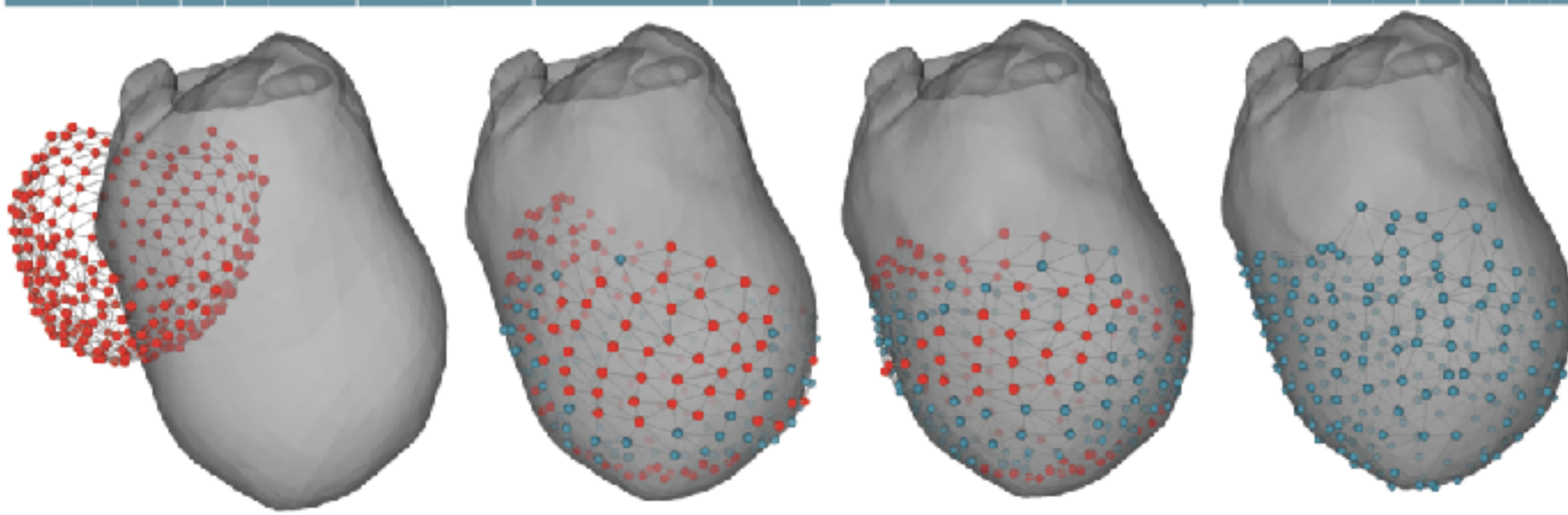
What to do with bad electrodes?



Dogrusoz, etal., CinC 2019

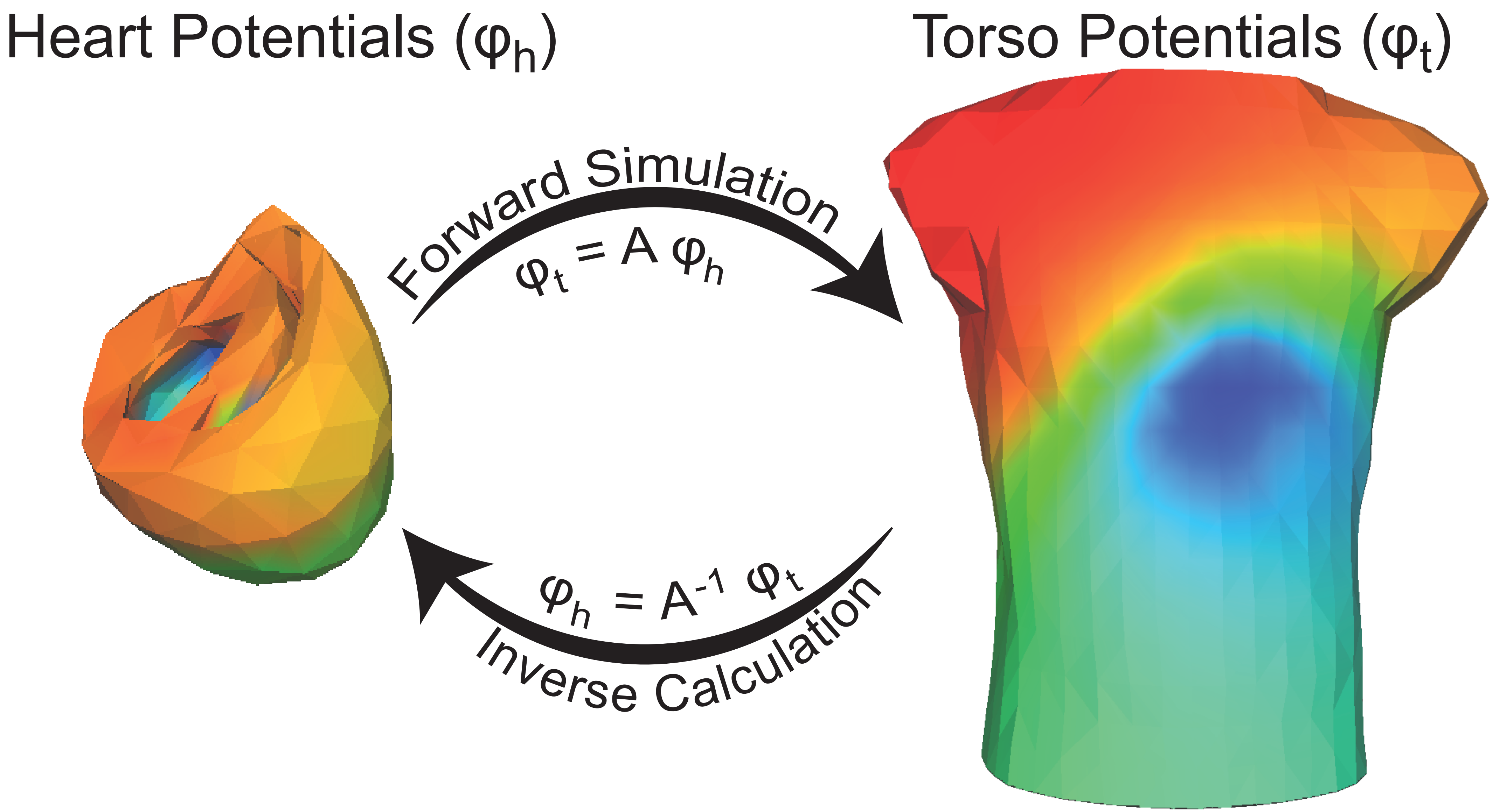
Registration Pipeline

GRÖMeR



Bergquist, etal. FIMH Thursday, 11:10

Improve ECGI



Quantify Uncertainty

Acknowledgements

People

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Jaume Coll-Font

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Steffen Schuler
Olaf Dössel
Jake Bergquist
Peter van Dam
Yesim Dogrusov

Data Submissions

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Nejib Zemzemi
Sophie Giffard-Roisin
Eric Perez-Alday
Peter van Dam

Datasets

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University Medical Centre Mannheim and the Karlsruhe Institute of Technology

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Nora Eccles Treadwell Foundation

Help From

Consortium for ECG Imaging (ecg-imaging.org)

Cardiac Arrhythmia Research Package (CARP)

More Submission Needed

https://challenge.kitware.com/

The image data for a nrrd file is a stream of numbers. The order of the data should iterate x first, then y, then z. If the data is a 3D matrix `M` of size `nx` by `ny` by `nz`, the data array (`D`) should match to the matrix index (`M[i,j,k]`) as:

```
D[i*nx*ny + j*nx + k] = M[i, j, k]
```

assuming zero based indexing and `i,j,k` are the indices for the `x,y,z` directions respectively. Make sure that the data type field in the header matches the value that the data will be written in. Now to write the file, write the header string , with a new line at the end, then write the data.

If there are questions, do not hesitate to ask.

Stage 2: Mesh Generation

With this stage we will quantify differences in meshing techniques used by different groups. We will be making the meshes based of an average of the submissions from Stage 1, therefore, we will have more details on this stage at a later time.

Stage 3: Forward Transform Matrix

With this stage we will quantify differences in techniques of calculating the forward matrix for ECG used by different groups. Again, we will base this calculation on a common input from the submissions from Stage 2, therefore, we will have more details on this stage at a later time.

PHASES FOR THIS CHALLENGE +

- Stage 1: Dalhousie Segmentation
- Stage 1: Auckland Segmentation
- Stage 1: Nijmegen Segmentation