

# AI in Cardiomyopathy - Discovery

Techniques Talk II

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# Declaration of Interests

- I have nothing to disclose



# Techniques

Algorithms	Input Data	Explanation	Interpretability
Statistical ML/DL	Derived Variables		Level 0
Deep Learning	Raw Images	Saliency Maps	Level 2
Deep Learning	Latent Representations	Saliency Maps	Level 2
Statistical ML	Latent Variables	Saliency Maps	Level 1

# Technique 1

Raw Images

Derived Variables (LV/RV mass,  
volumes, EF, strain, etc)

Statistical ML/DL for  
prediction/classification/regression

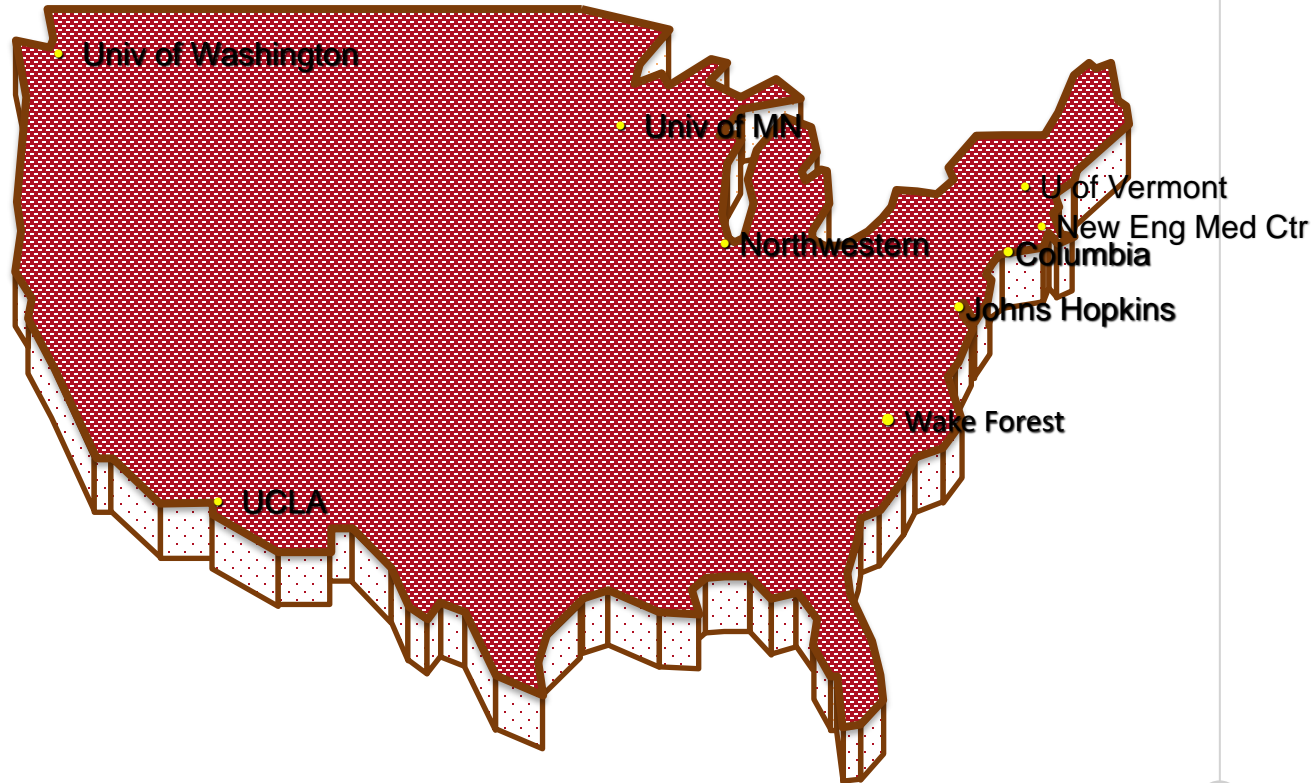
# Multi-Ethnic Study of Atherosclerosis



- Initiated in 1999-2000
- 6,834 subjects
- Average age=62 years at baseline (range: 45-85)
- 53% women
- Multi-Ethnicity
  - White
  - African-American
  - Hispanic
  - Chinese-American

Events over 12 years of follow-up

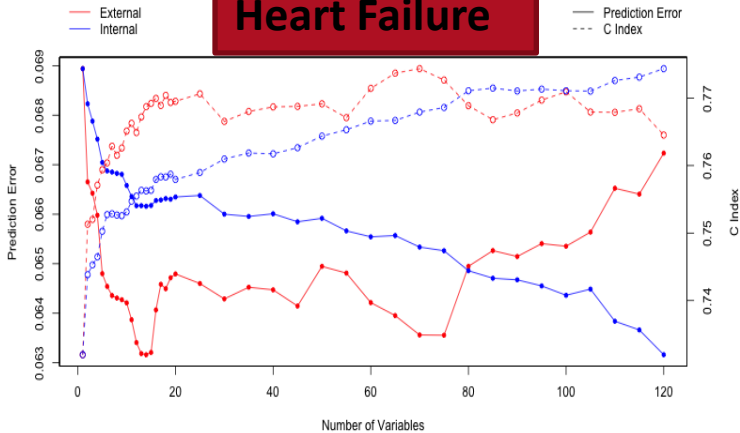
- Congestive heart failure
- Mortality
- CVD
- Stroke
- CHD
- Atrial Fibrillation



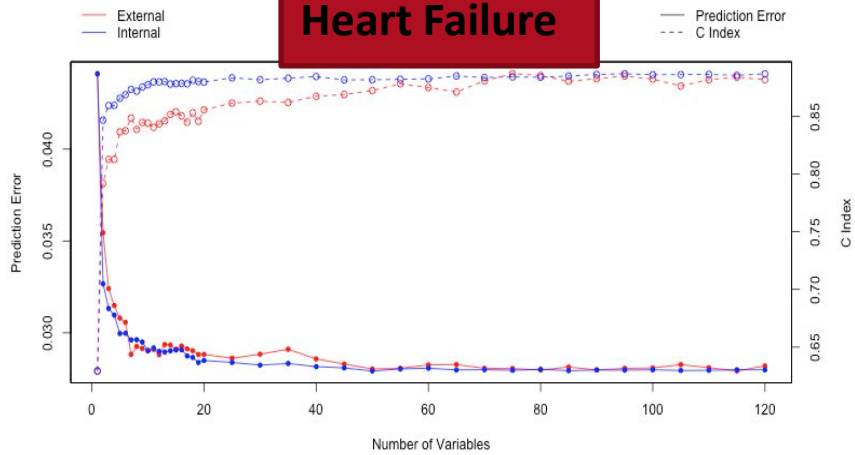
# Cox Regression vs Random Survival Forests

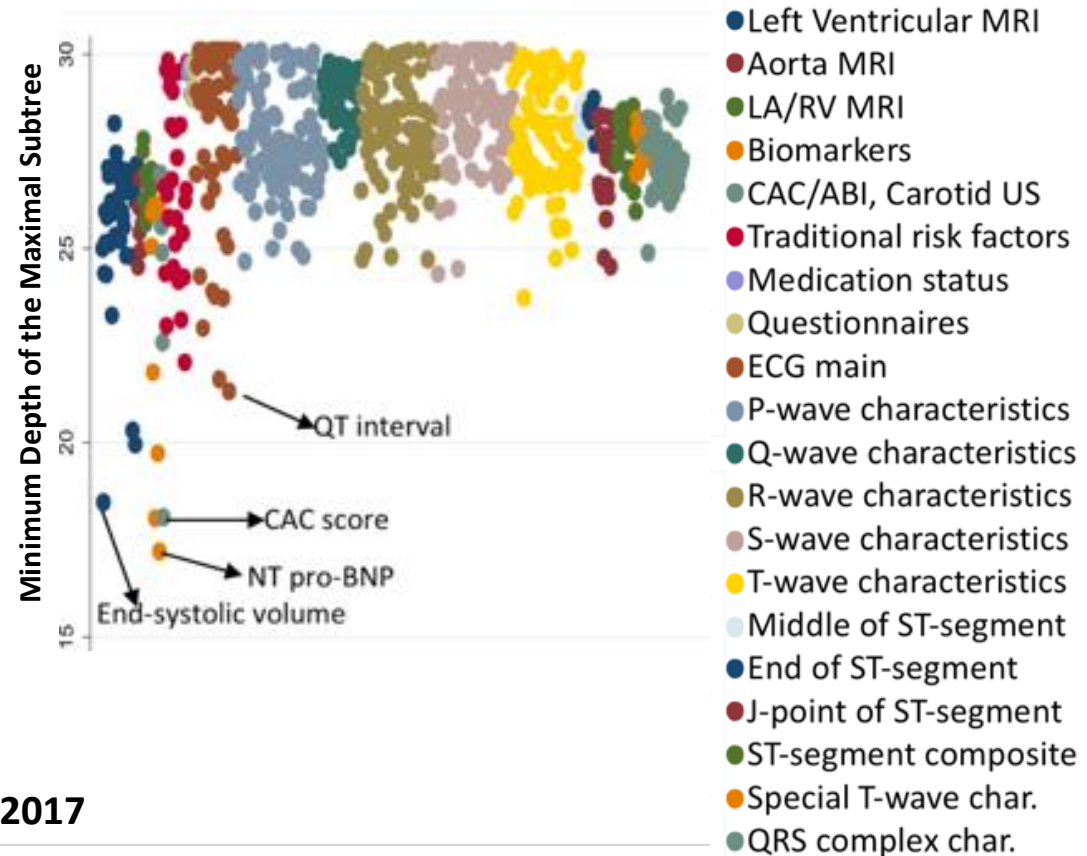
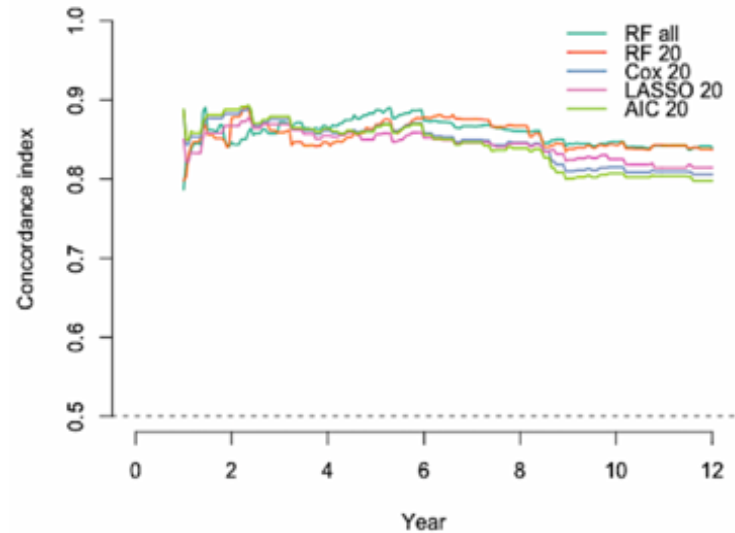


## Heart Failure

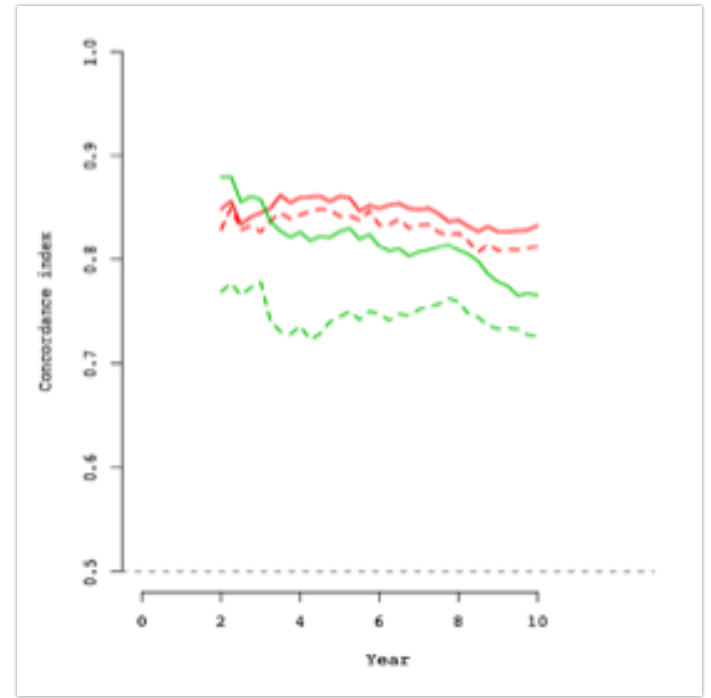


## Heart Failure





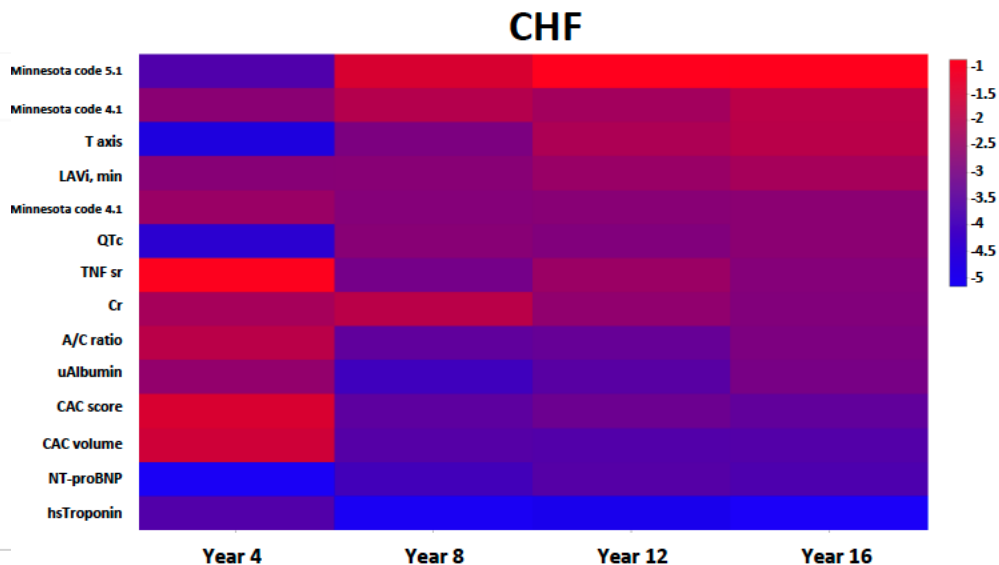
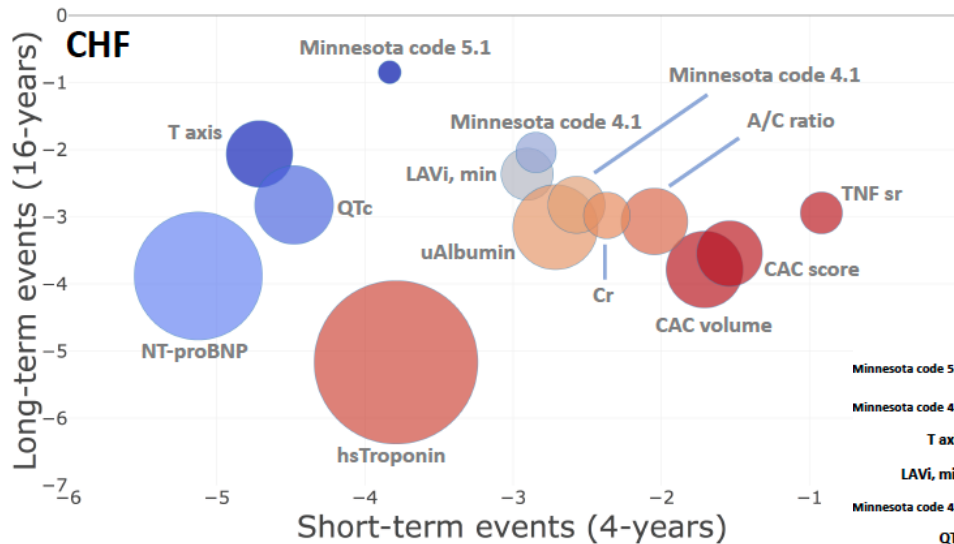
Rank	Heart Failure
1	N-Terminal pro-Brain Natriuretic Peptide
2	Tissue Necrosis Factor- $\alpha$ soluble receptor
3	Coronary Artery Calcium score
4	End-systolic left ventricular volume
5	Cardiac Troponin-T
6	End-diastolic left ventricular volume
7	Left ventricular ejection fraction
8	QTC INTERVAL
9	QT Index
10	Interleukin-2 soluble receptor
11	Waist-to-hip ratio
12	Ankle-Brachial Index
13	PR INTERVAL
14	Creatinine
15	Pulse pressure
16	End-diastolic left ventricular mass
17	Estimate of overall heart rate variability
18	T Amplitude in Lead V1
19	Minnesota code 1 score: V lead group
20	Minnesota code 1 score: F lead group



Solid Curve: Variables with MRI,  
Dotted Curve: without MRI Variables;  
Green: Cox, Red; RSF

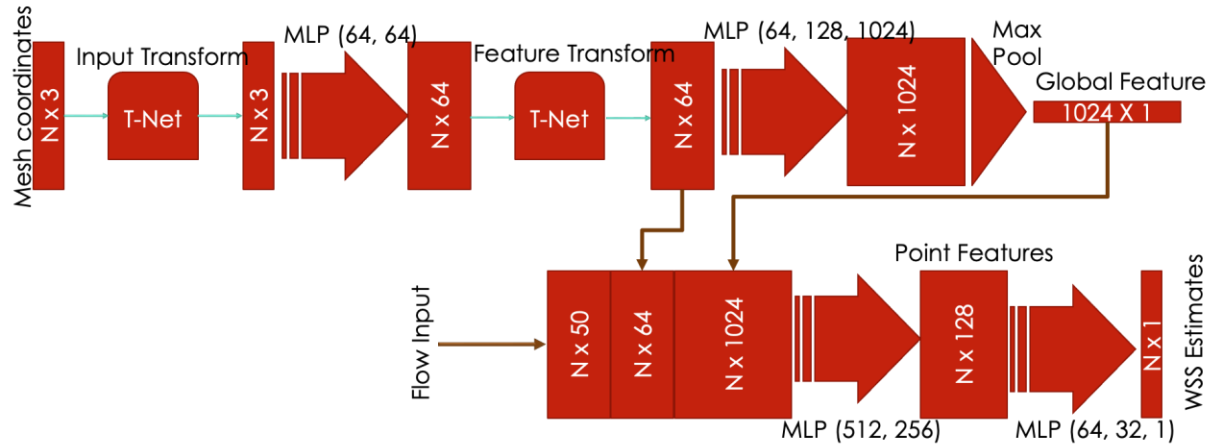


# Short vs Long-term event prediction

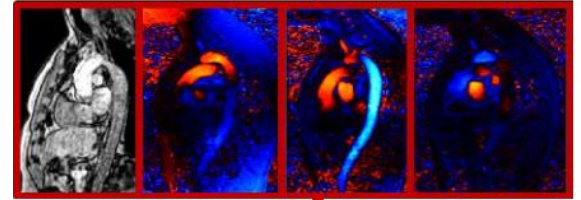


Ostovaneh et al, under review

# Aortic Wall shear stress assessment



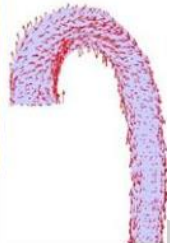
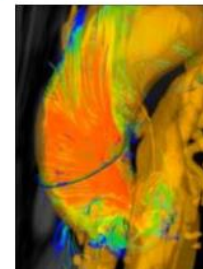
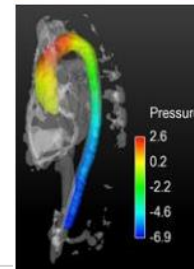
## 4D Flow Acquisition



**Pressure**

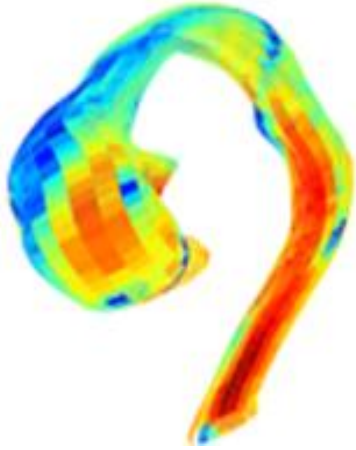
**Vorticity**

**WSS**



## Example case

4D-flow based wall shear stress



DL-based wall shear stress



## Technique 2

Raw Images + Clinical Data

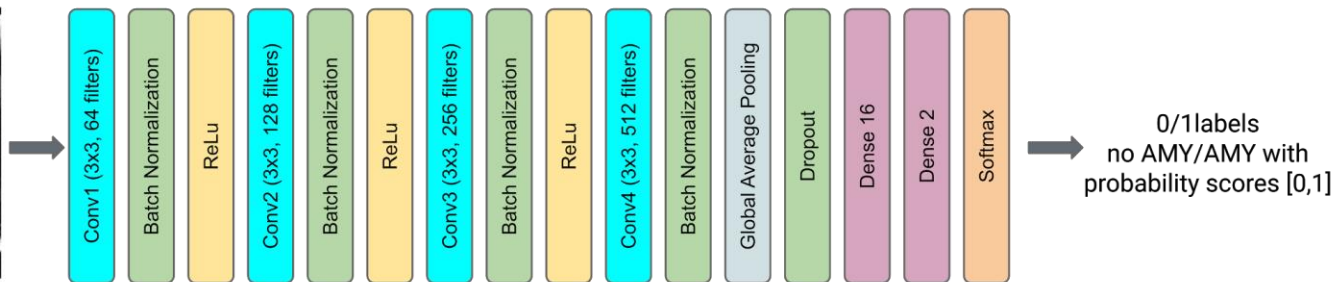
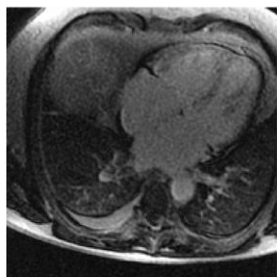


DL Network

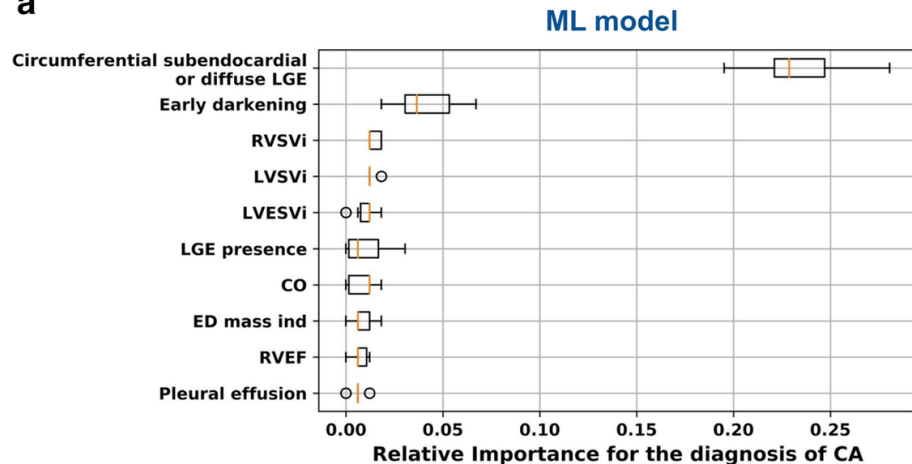


Prediction/Classification

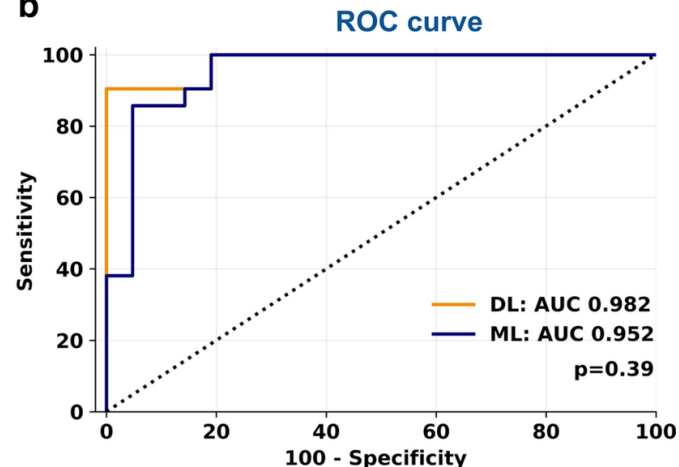
# Amyloidosis Detection by DL/ML



a



b

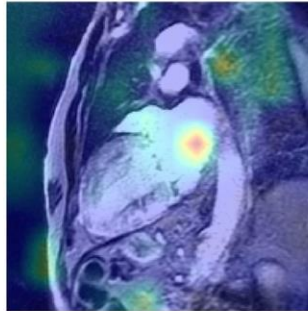


# Interpretation

a

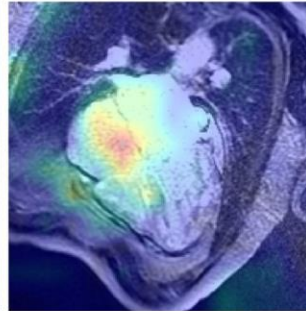
Likelihood of CA

99%



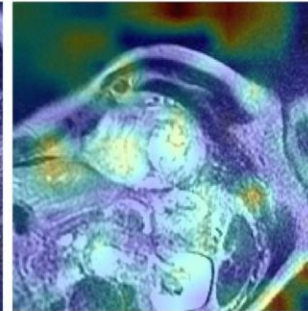
2C

60%



4C

88%

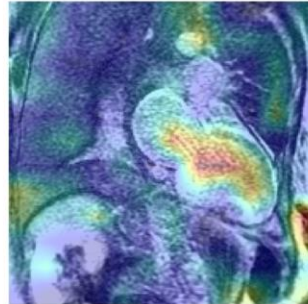


SA

b

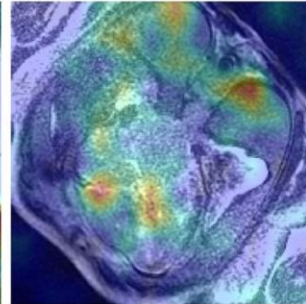
Likelihood of CA

99%



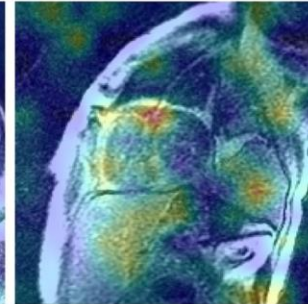
2C

97%



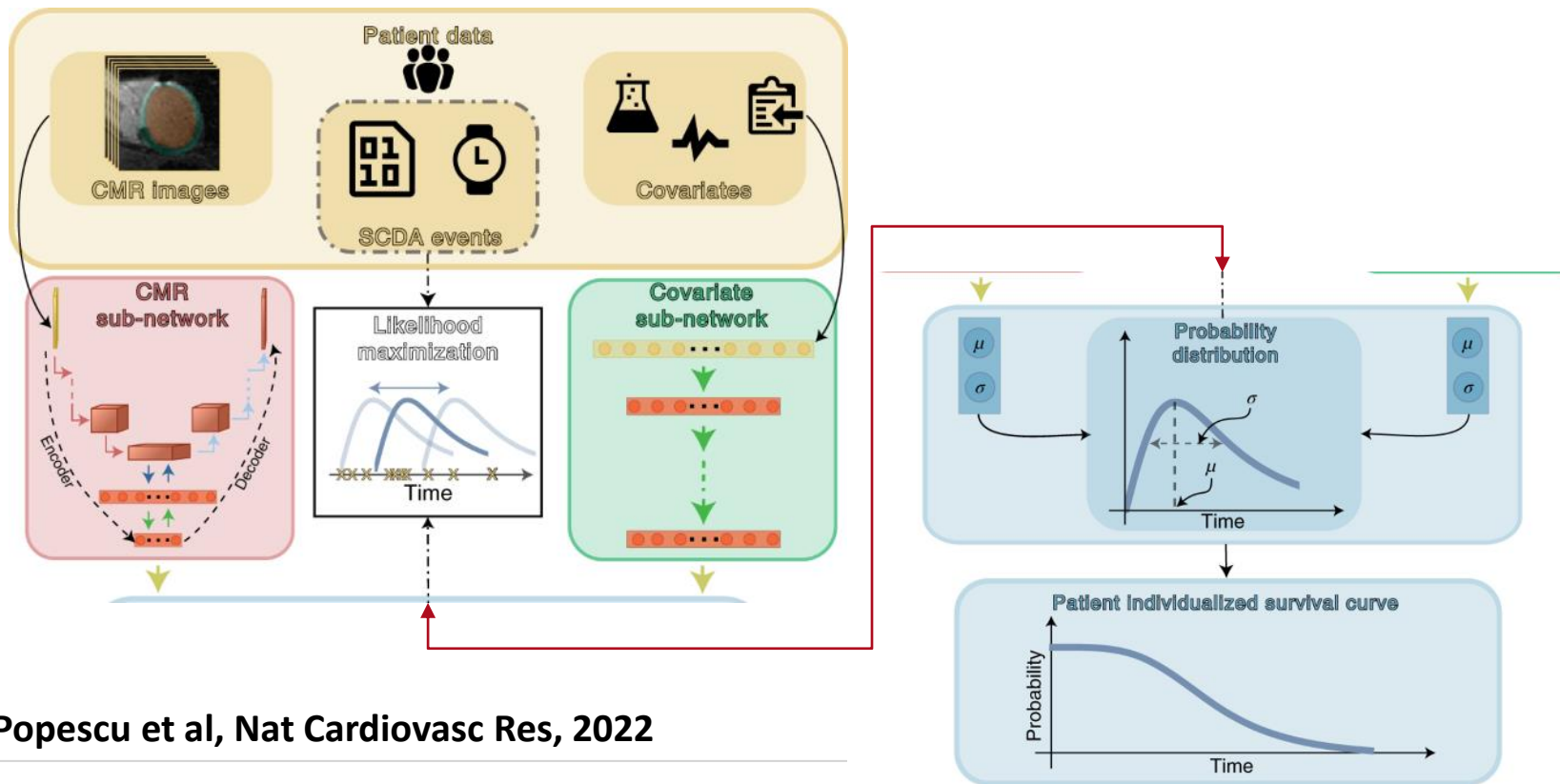
4C

91%

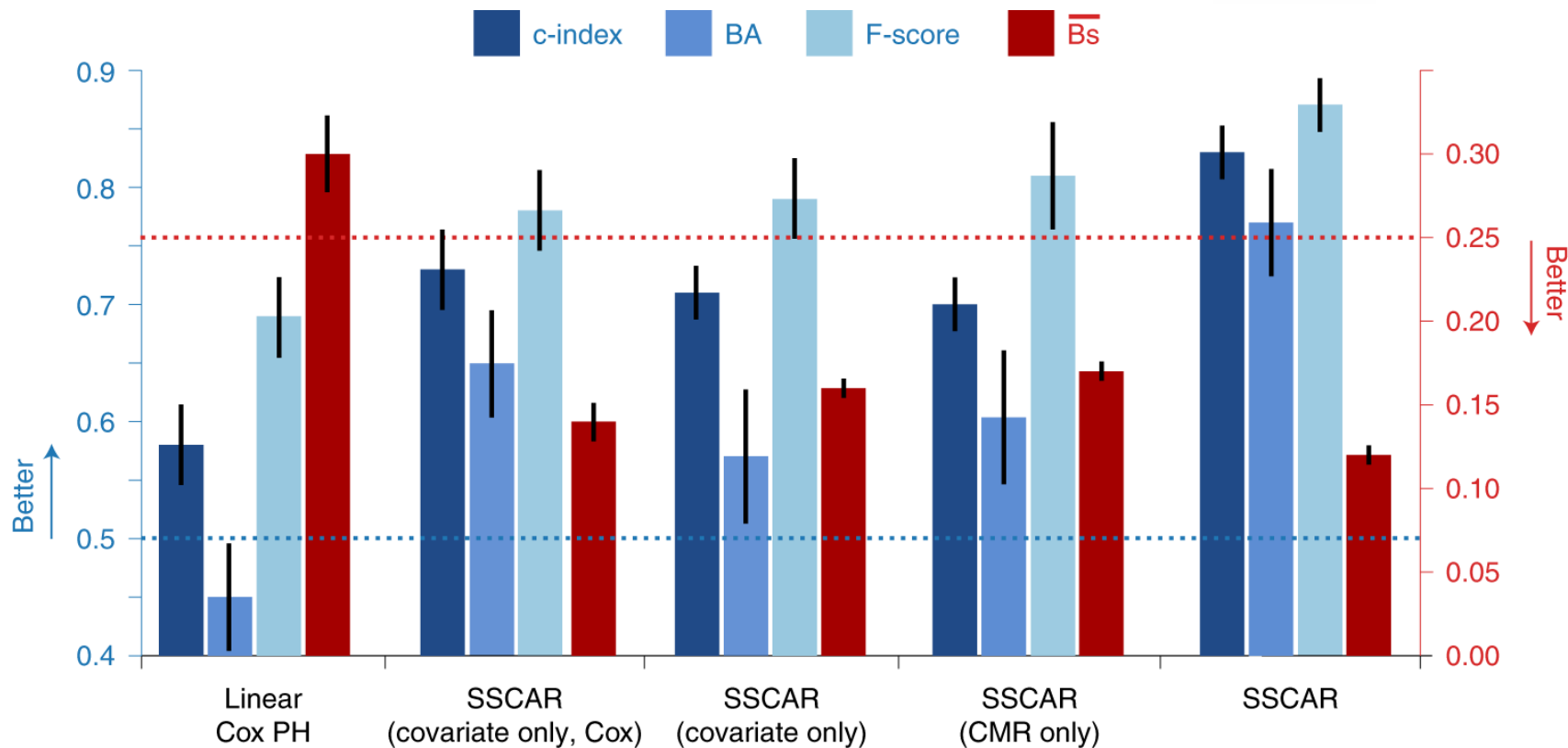


SA

# Integration of Raw Images and Covariates for Prediction of Sudden Cardiac Death

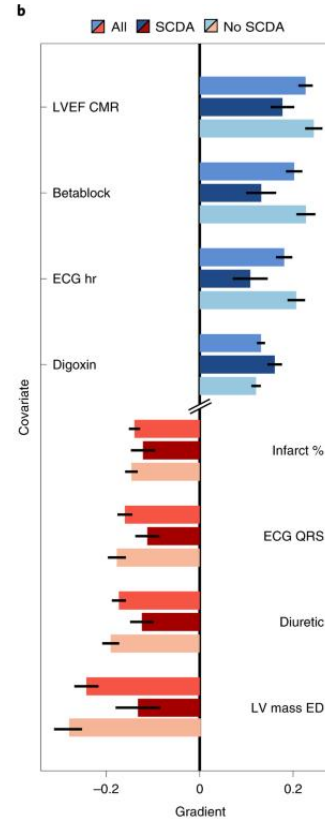
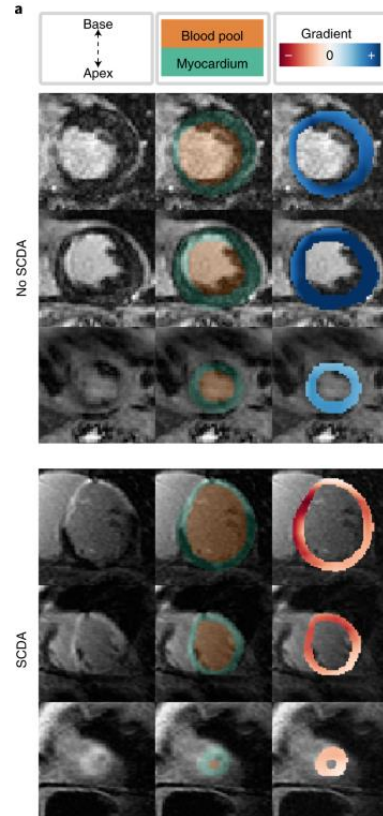


# Performance Comparison





# Interpretation



# Technique 3

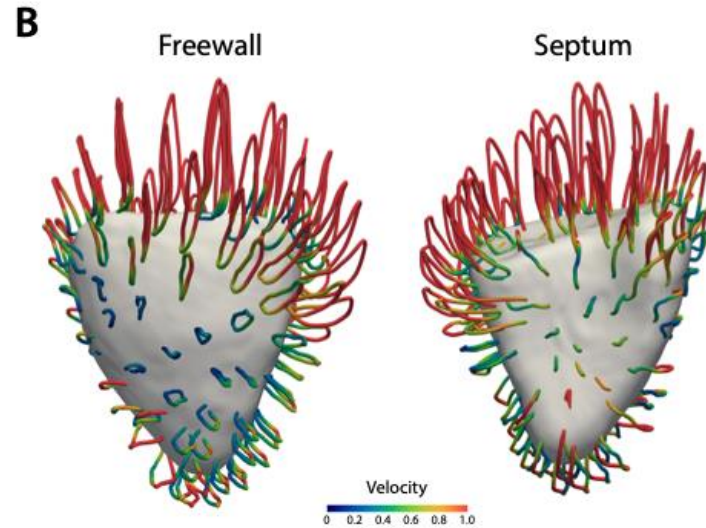
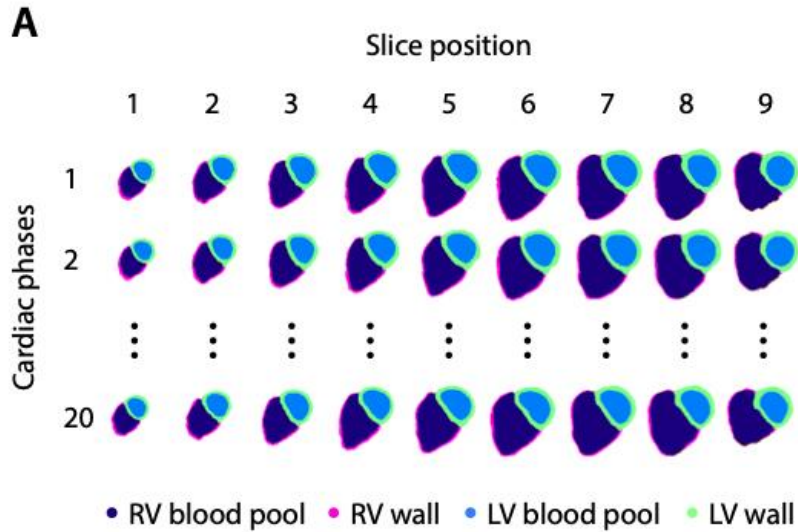
Raw Images

3D Point Clouds/Representations  
(LV/RV mesh points from modeling)

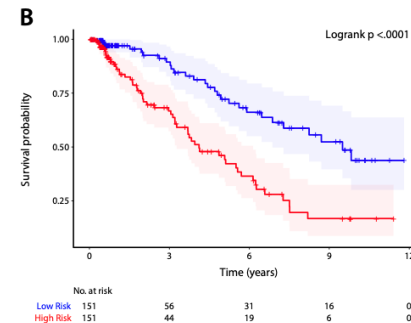
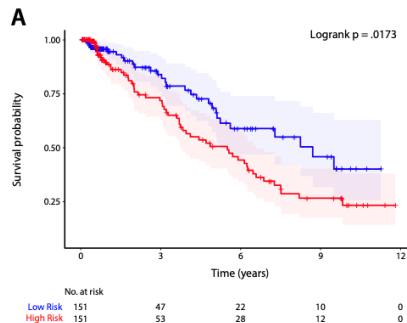
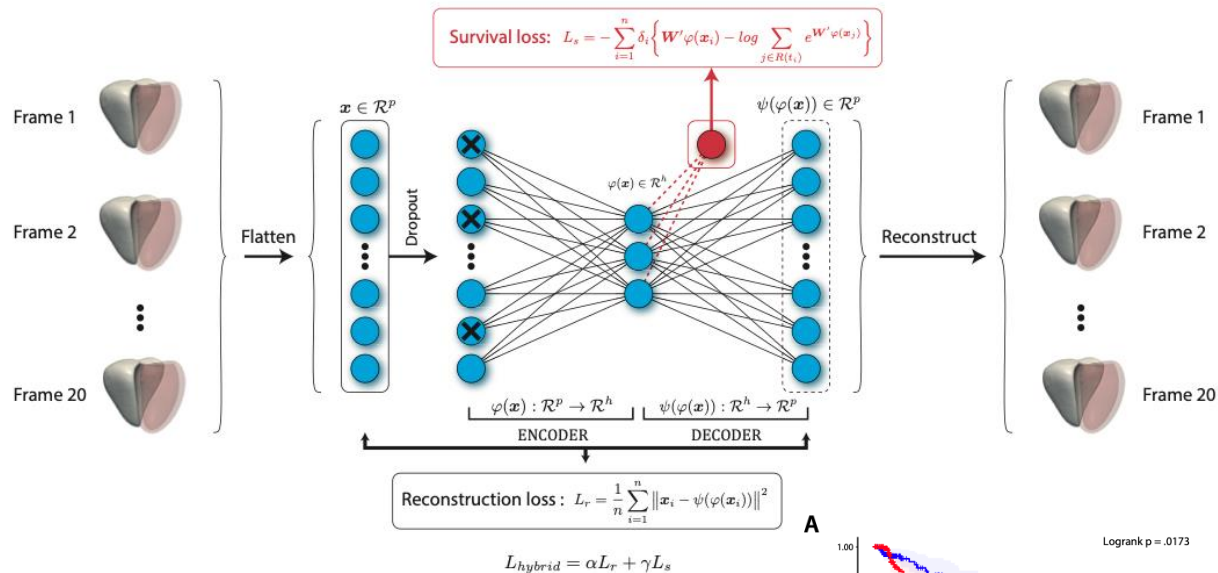
DL for  
prediction/classification/regression

Bello et al

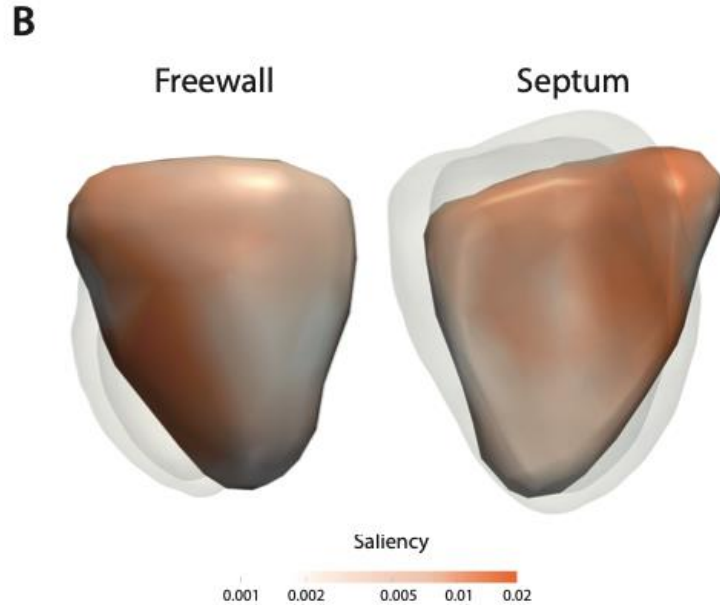
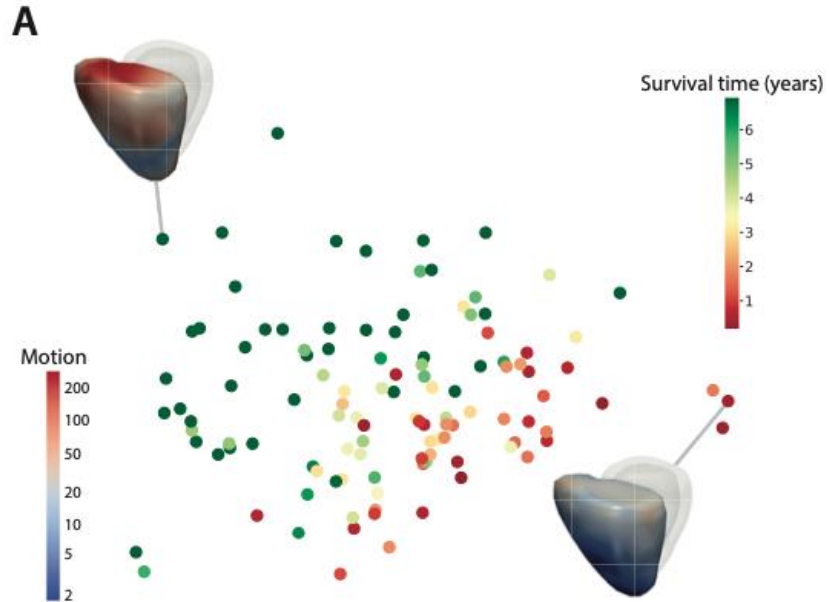
# Generation of features from raw images



# Generation of latent code



# Interpretation



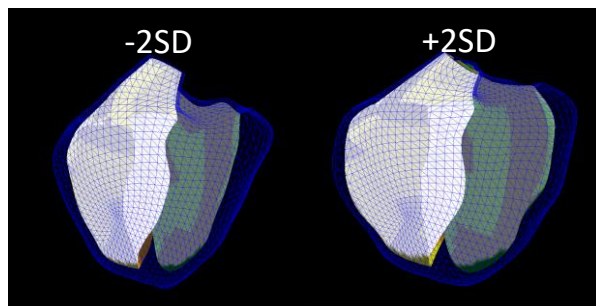
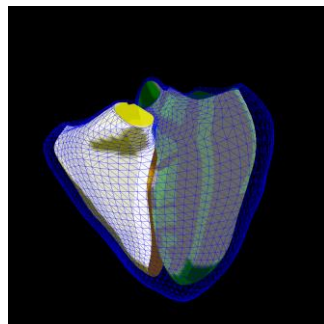
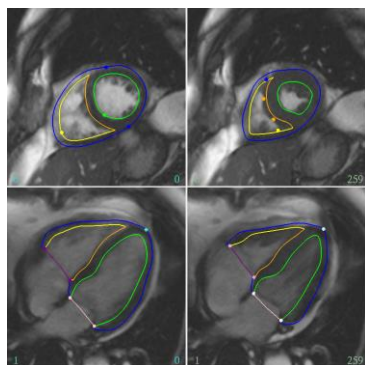
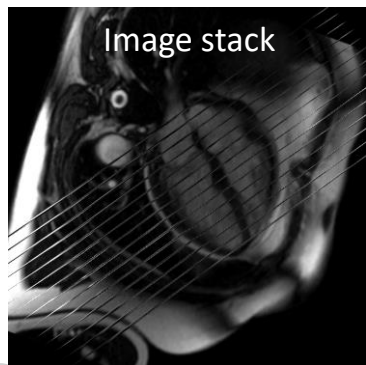
# Technique 4

Raw Images

3D Point Clouds/Representations (LV/RV  
mesh points from modeling) + Clinical Data

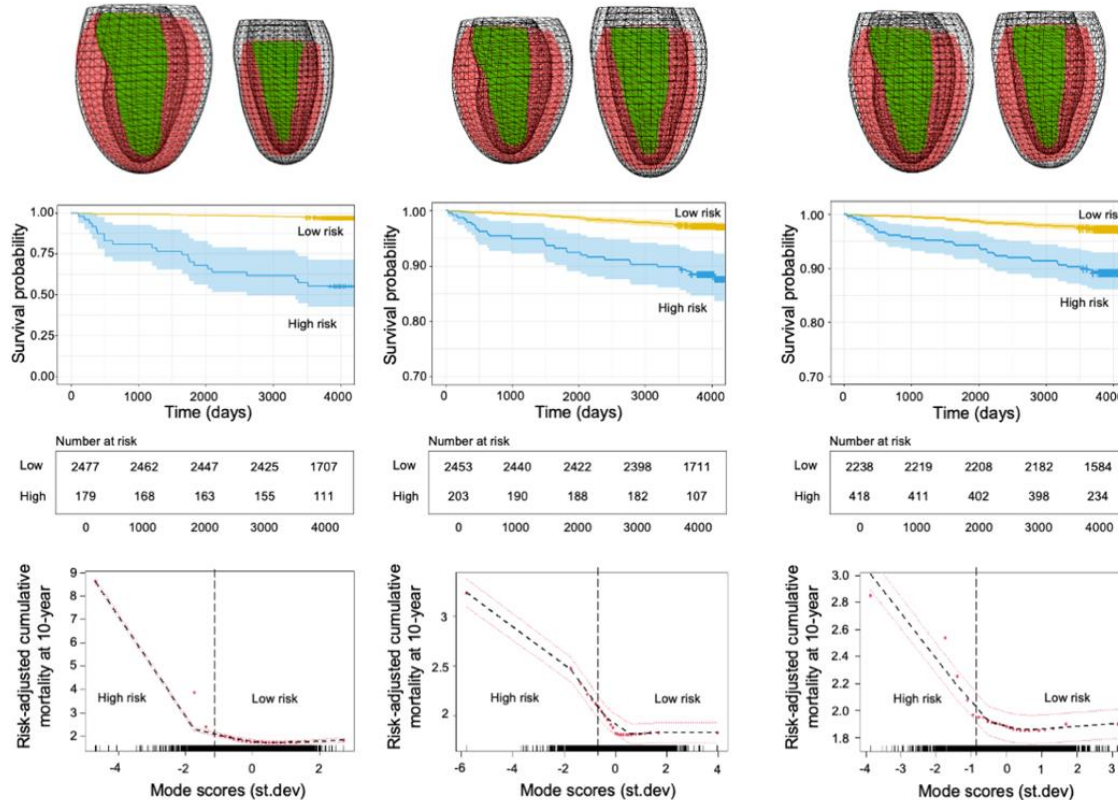
ML for prediction/classification/regression

# Pipeline with a goal of prediction





# Event-Specific Shape Modes

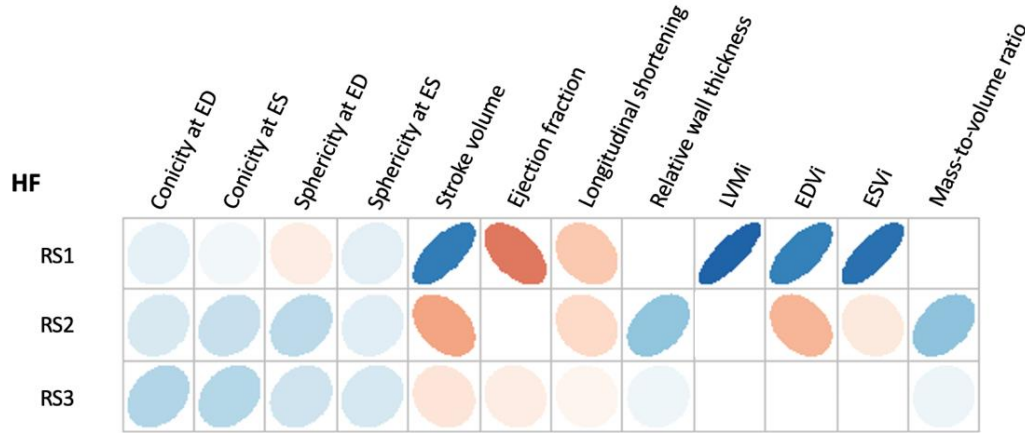


## Partial Least Squares- Cox

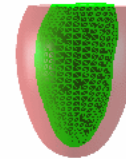
- Is event-specific
- Can easily find the optimal number of modes
- Variations can include other biomarkers and clinical data to create a person-specific model



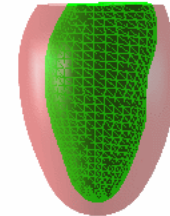
# Event and Person-Specific Shape Modes



Low risk



High risk



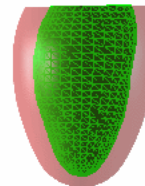
CHF

*Selected variables*

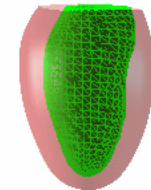
*Hazard ratios [95% confidence intervals]*

NT-proBNP	1.70 [1.34,2.15]
Age	1.07 [1.05,1.10]
Fasting glucose	1.03 [1.01,1.06]
Resting Heart Rate	1.01 [1.01,1.02]
RS1	0.55 [0.47,0.63]
RS2	0.66 [0.54,0.83]
RS3	0.72 [0.59,0.89]
SBP	0.98 [0.80,1.20]

Low risk



High risk



# Conclusions

- **Several approaches to discovery of imaging markers**
- **Key aspects to consider when establishing a marker are:**
  - Relationship with outcomes
  - Improvement over existing markers
  - Explainable (Latent Modes, Activation Maps)
  - Ease of use
  - Actionable (modulated by risk factors, interventions, biomarkers, etc)
  - Trackable (can it be used as an outcome in clinical trials, patient monitoring)

# Acknowledgements



- Joao A C Lima
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