# Capturing cardiac anatomy and function with AI models

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SCMR

Society for Cardiovascular Magnetic Resonance

EACVI

European Association of Cardiovascular Imaging

European Society of Cardiology

# DoI

- **Founder and shareholder, AiSentia**

- **Group research partly funded by**
  - Perspectum
  - Philips
  - GE Healthcare
  - IBM

# Aims

- **Capturing healthy anatomy/function and variability**
  - 3D analysis
  - Includes electrophysiology and mechanics
  - Natural and pathological variability

- **Apply these models to clinical questions**

- **Mostly using CMR – UK Biobank**

# Methodology: building 3D representations from CMR scans

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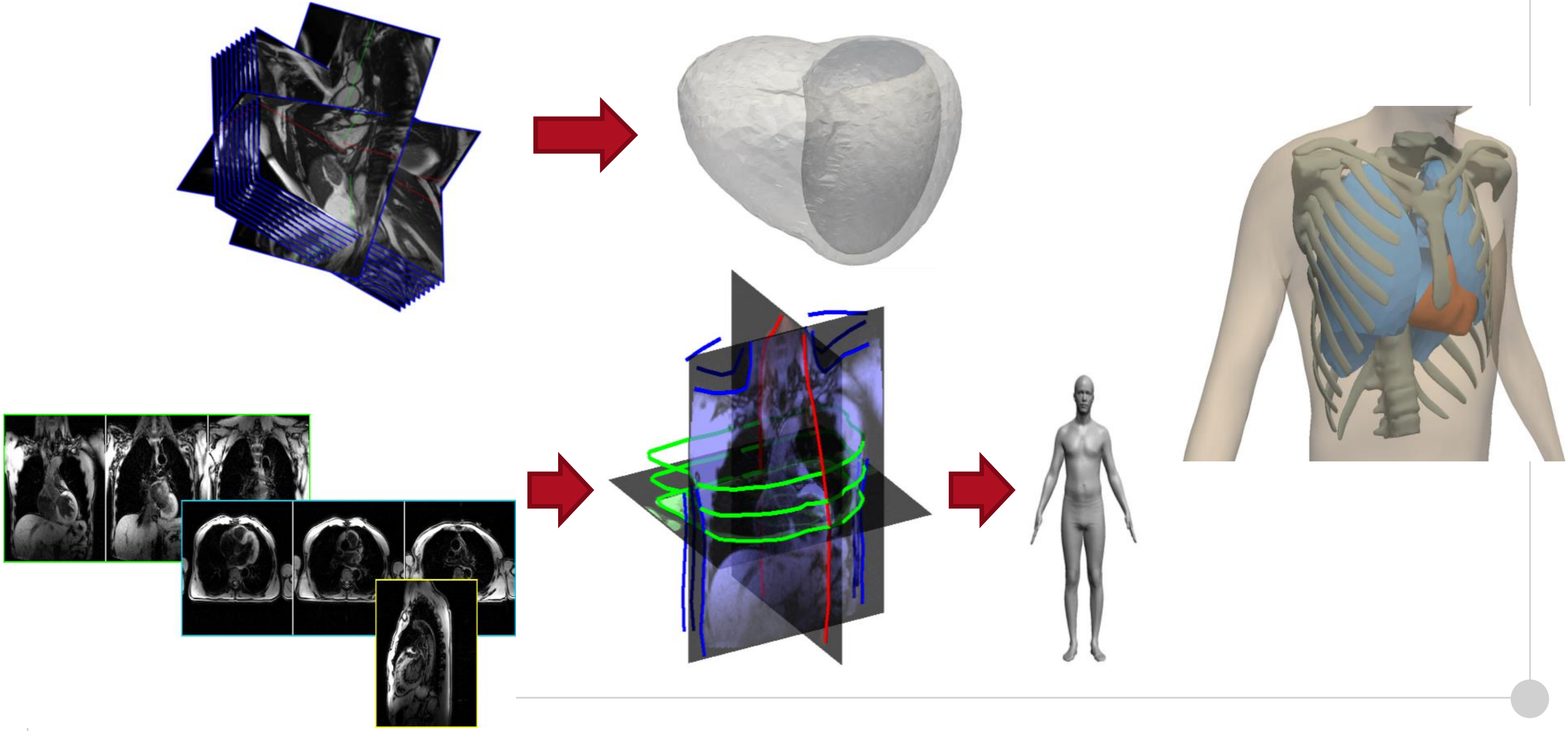
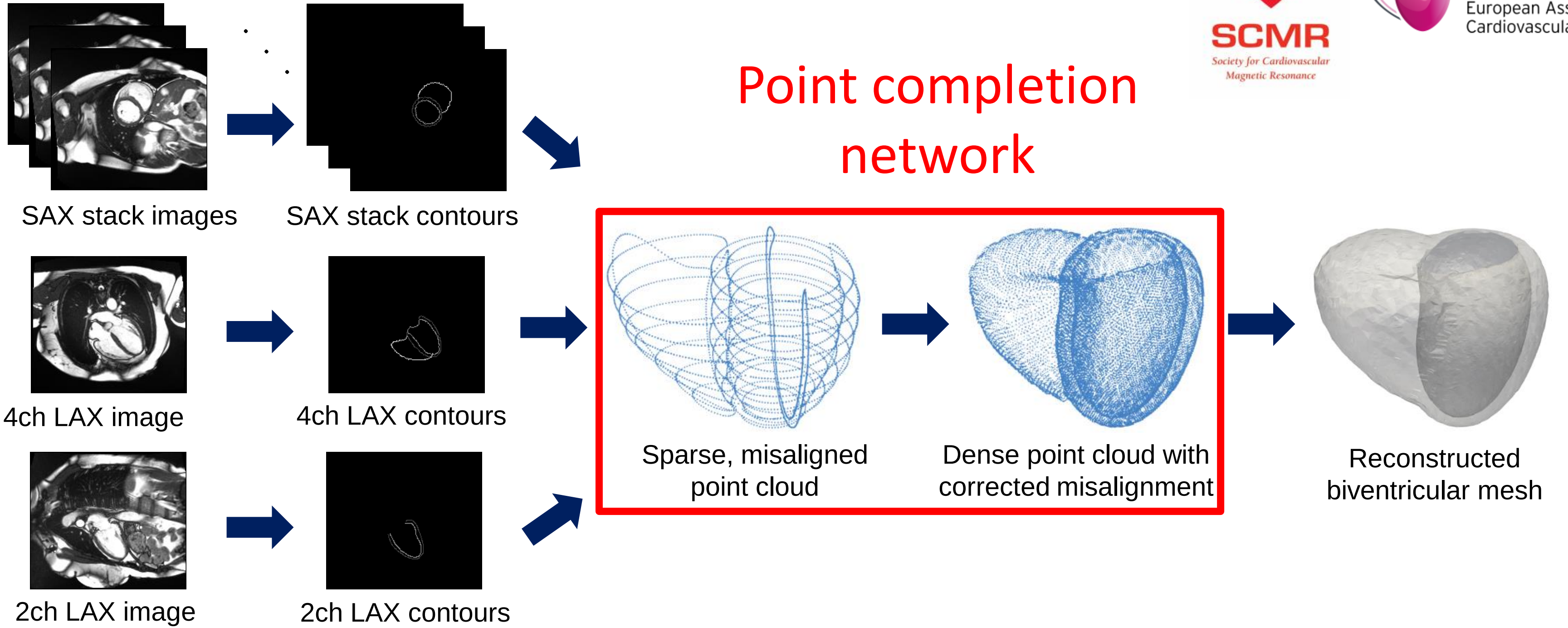


# Point completion network




1 **Segment SAX and LAX images**

2 **Convert contours to 3D point cloud**

3 **Point Completion Network**

4 **Meshing algorithm**

Segmentation: [Bai et al, JCMR 18]

Marcel Beetz, Abhirup Banerjee [Stacom 21]

# Reconstructions from UK Biobank

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Apply Point Completion Network to cine MR images of the UK Biobank

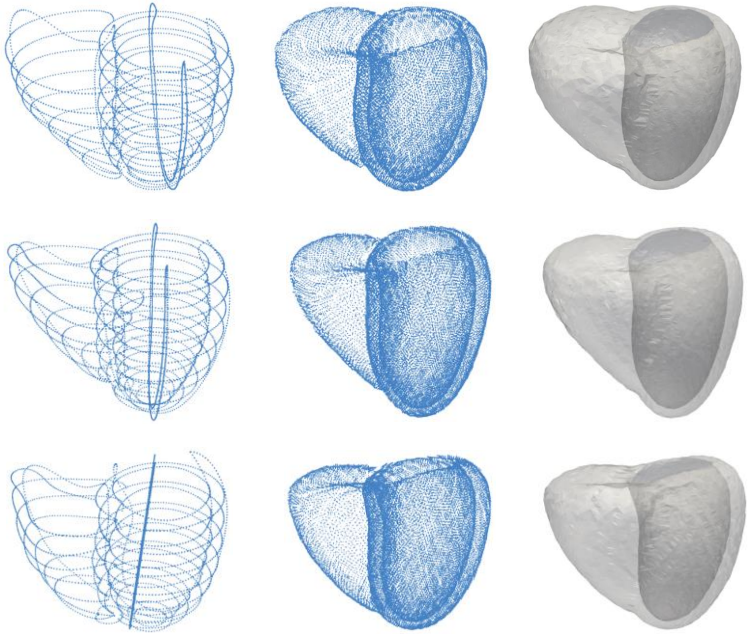
Left ventricular volumes of reconstructed meshes are **in line with established clinical reference** ranges and error estimates

**Table 2**: Comparison of UKB results with references values

| | Ours | Petersen et al. [18] |
|---|---|---|
| LV ED Volume (ml)[1] | 112 ($\pm$11) | 124 ($\pm$21) |

[1] Values represent *mean* ($\pm$ *SD*).

Sparse, misaligned input point cloud | Dense output point cloud | Output mesh



# Predicting Major Adverse Cardiac Events post MI

## PRINCIPAL COMPONENT ANALYSIS (PCA)

ES Shape - Septal view - MEAN

J. Corral Acero et al. "Understanding and Improving Risk Assessment after Infarction: AI-Enabled Study of 3D Left Ventricular Patterns". *JACC Cardiovasc Imaging 2021*

# ES Shape risk-related patterns

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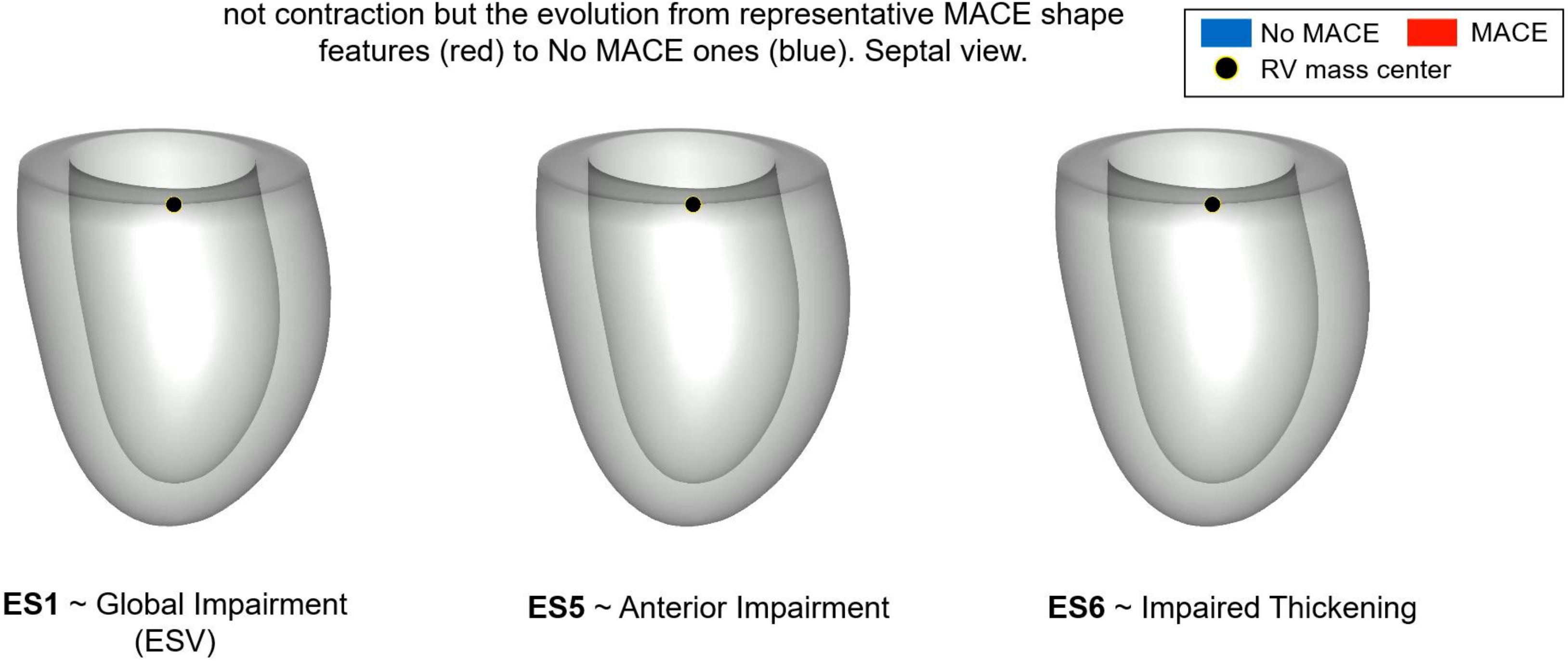
## End-Systolic Shape

Interpretability of the ES shape descriptors found prognostic. This is not contraction but the evolution from representative MACE shape features (red) to No MACE ones (blue). Septal view.




J. Corral Acero et al. "Understanding and Improving Risk Assessment after Infarction: AI-Enabled Study of 3D Left Ventricular Patterns". *JACC Cardiovasc Imaging 2021*

*al*

# 3D Contraction risk-related patterns

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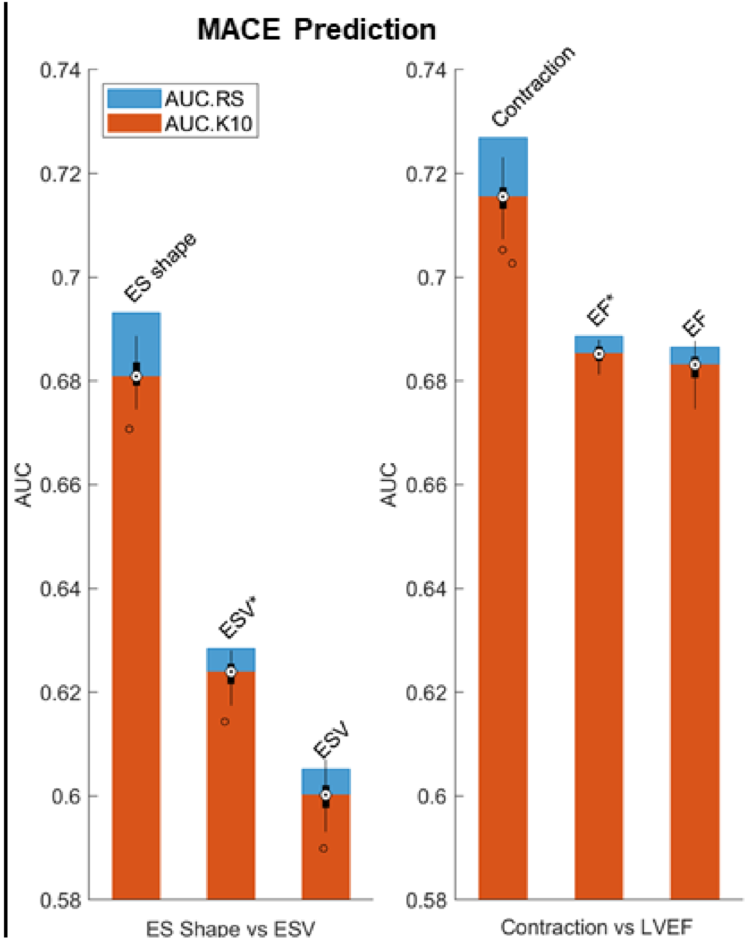
## Contraction

Interpretability of the 3D contraction descriptors found prognostic. Contractions are applied on the mean ED shape and visualized as resulting ES shapes. This does not illustrate contraction over time but the evolution from the resulting representative MACE shape features (red) to No MACE ones (blue). Septal view.

- MACE
- No MACE
- Mean ED Shape
- RV mass center

**C3** ~ Global Impairment (LVEF) | **C5** ~ Anterior Impairment | **C16** ~ Basal Impairment

J. Corral Acero et al. “Understanding and Improving Risk Assessment after Infarction: AI-Enabled Study of 3D Left Ventricular Patterns”. *JACC Cardiovasc Imaging 2021*

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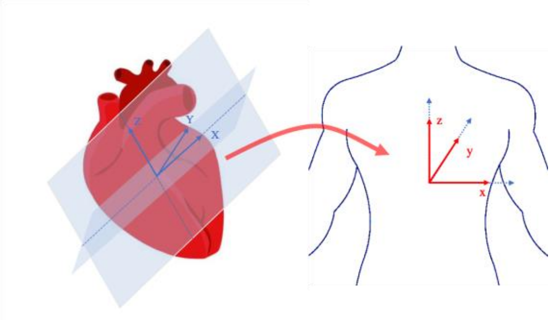
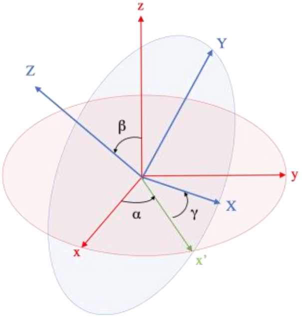
*J. Corral*

# Capturing ECG patterns

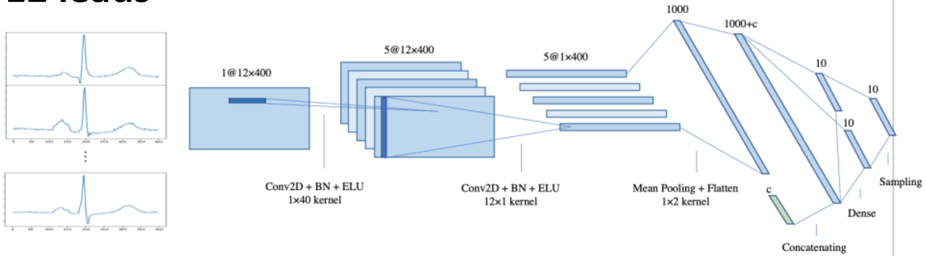


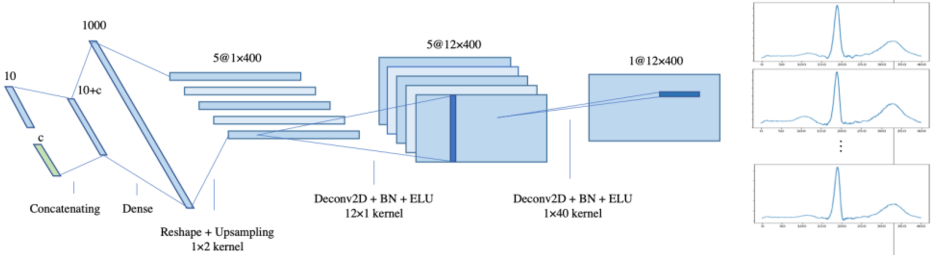

## Conditional VAE

- Encoder

**12 leads**




- Decoder

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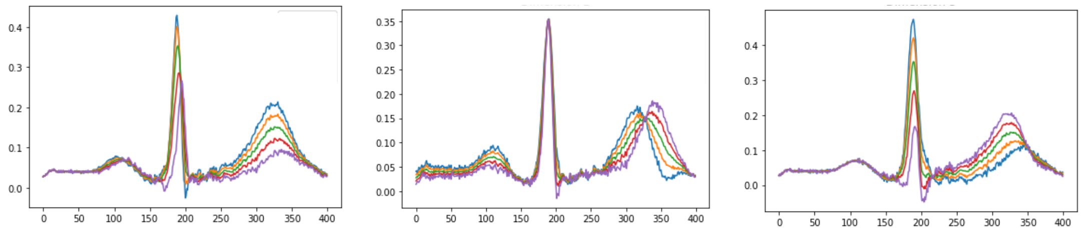
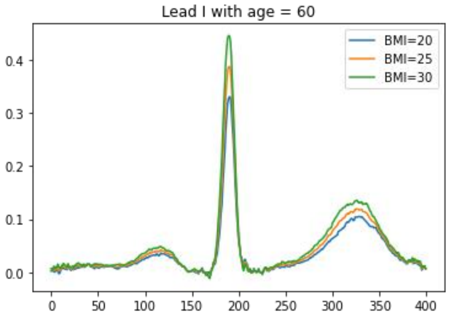
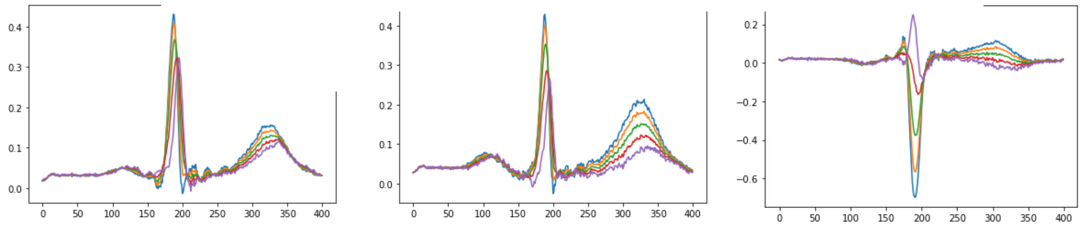
# Variation of different modes in single lead



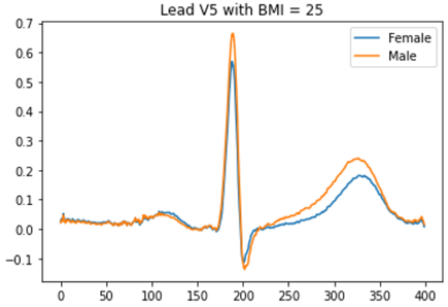
## BMI on Lead 1




# Effect of single mode on multiple leads



## Gender on Lead V5

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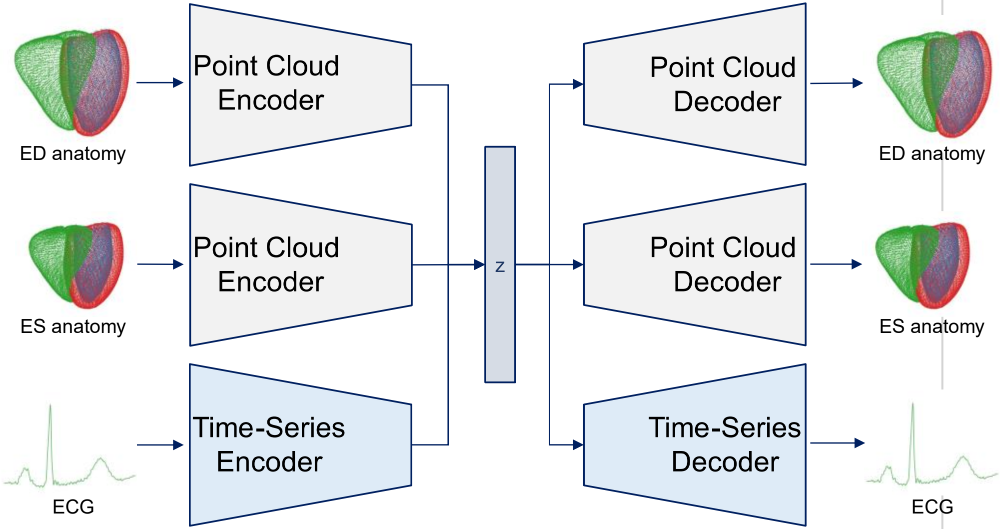
# Capturing multimodal ECG/anatomy patterns

- Three different **branches** tailored to each **modality**
- All branches **share latent space**
- **Anatomy branches** based on **point cloud**-based **deep learning**
- **ECG branch:** combination of **convolutional, pooling**, and **fully connected** layers




Marcel Beetz, Abhirup Banerjee, Frontiers in Physiology, accepted for publication

# Experiments - Generative Ability

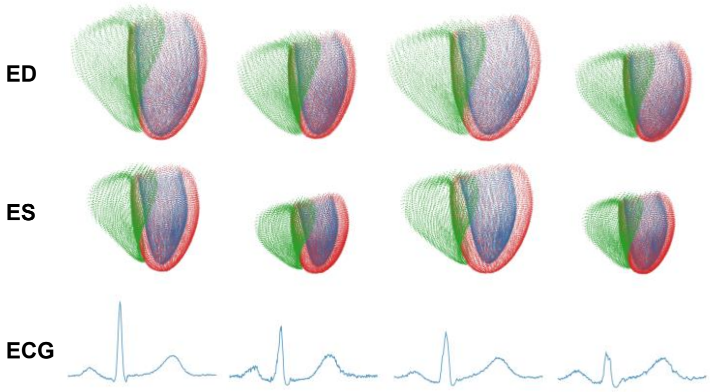



**Table 4.** Clinical metrics of ED and ES anatomy point clouds.

| Phase | Clinical Metric | Gold Standard | Ours |
|---|---|---|---|
| ED | LV volume (ml) | 141 (±30) | 139 (±31) |
| | RV volume (ml) | 170 (±34) | 176 (±37) |
| ES | LV volume (ml) | 59 (±15) | 58 (±16) |
| | RV volume (ml) | 78 (±20) | 80 (±24) |
| ED/ES | LV mass (g) | 102 (±28) | 99 (±29) |

Values represent mean (± standard deviation) in all cases.

- Method generates **realistic** and **diverse** bitemporal **anatomies** and **ECGs**
- **Comparable clinical metrics** between generated and test dataset **anatomies**

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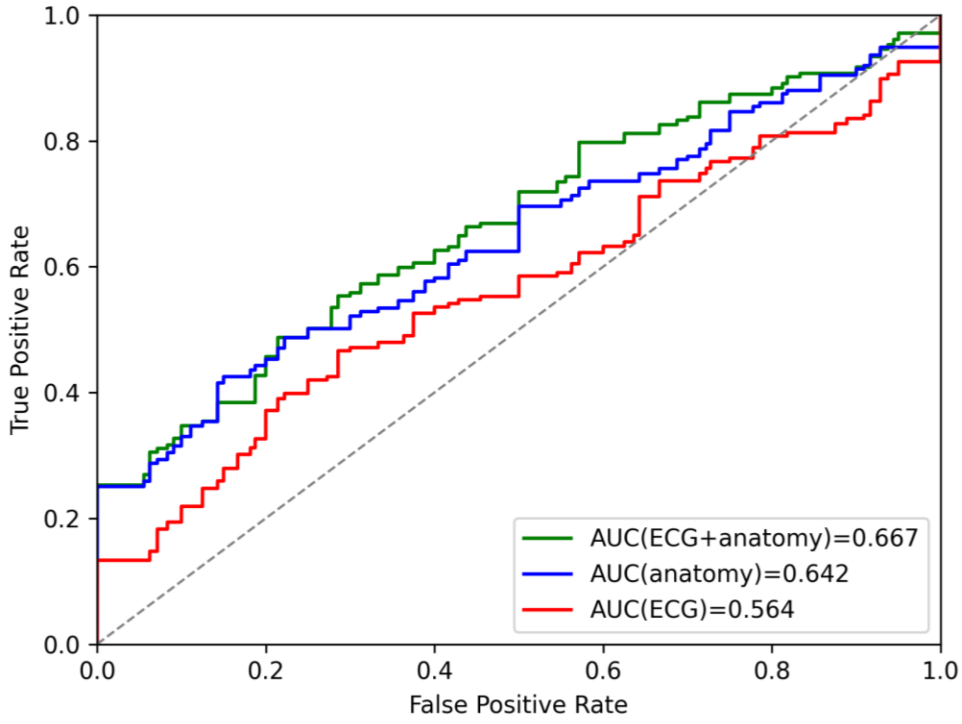
# Classification based on latent space: mono vs multimodal

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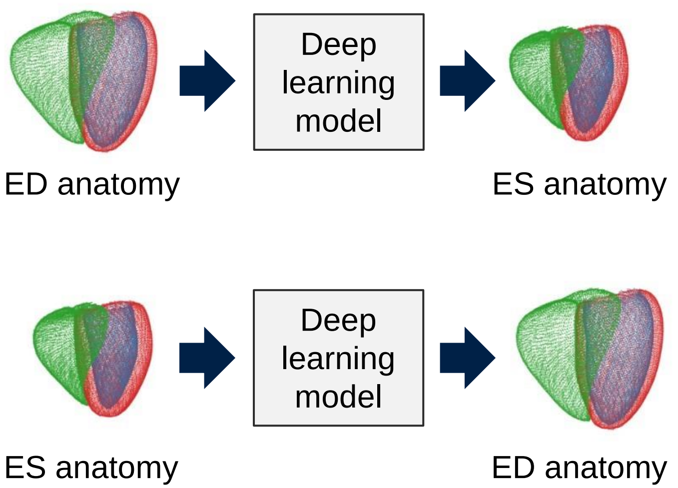
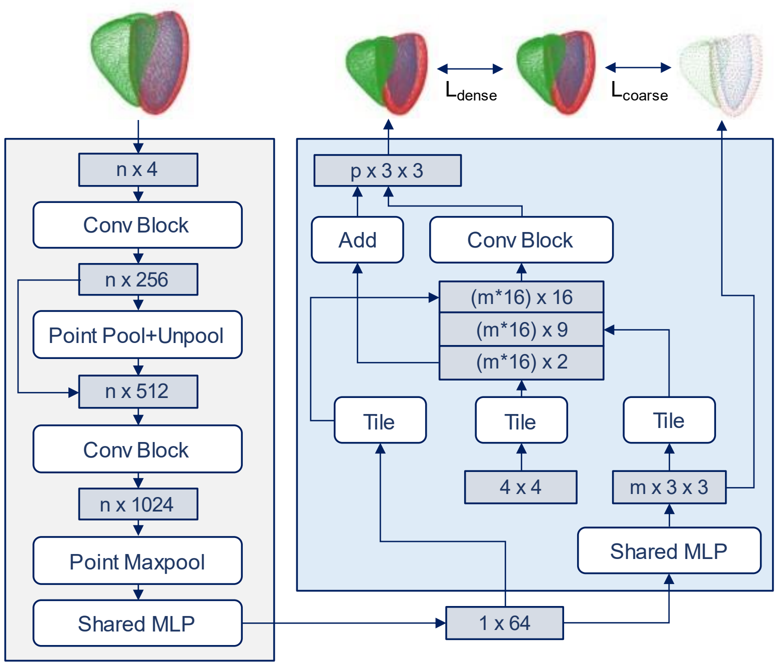
# Capturing mechanical function

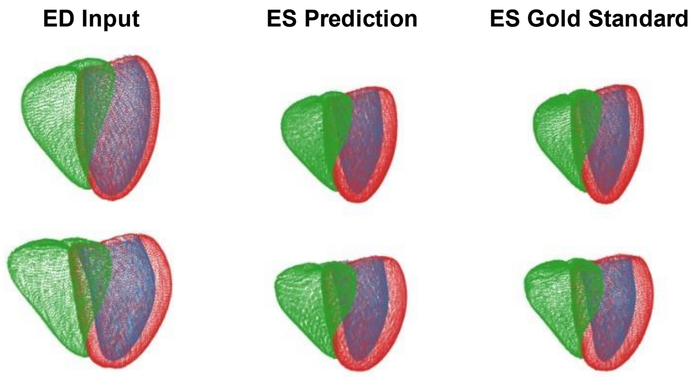


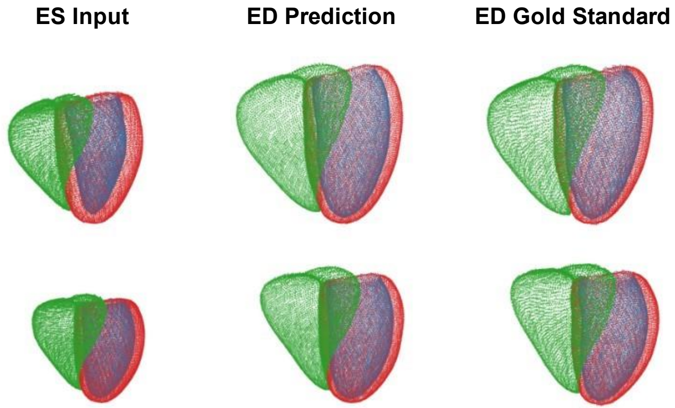




**Point cloud autoencoder**

Marcel Beetz, Abhirup Banerjee, Stacom 2021

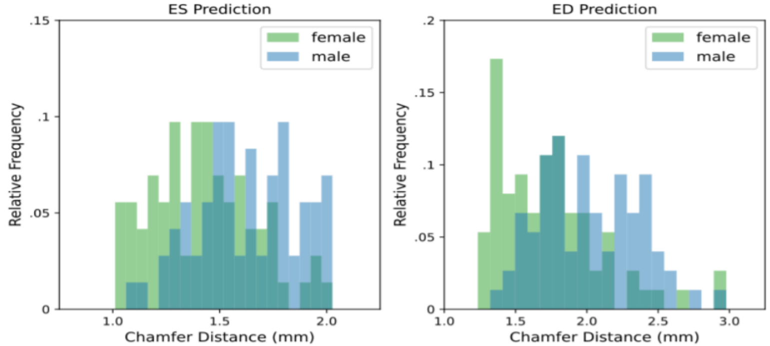
# Prediction results




| Clinical Metric | Gold Standard | ES Prediction | ED Prediction |
|---|---|---|---|
| LV EF (%) | 59 (±7) | 60 (±6) | 59 (±6) |
| LV SV (ml) | 83 (±19) | 83 (±20) | 80 (±16) |
| RV EF (%) | 62 (±21) | 62 (±19) | 60 (±19) |
| RV SV (ml) | 93 (±25) | 94 (±19) | 92 (±26) |

Values represent mean (± standard deviation).



# Conclusions

- Generative models can capture natural variability in anatomy and function
- Multimodal models are feasible and show improved performance
- Models capture differences between subpopulations
- Strong synergy with physics-based models

# Acknowledgments

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