Patient-specific multi-scale modeling of cardiac resynchronization therapy for dyssynchronous heart failure

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UCSD Jacobs | Department of Bioengineering

Background

- Heart failure is the leading cause of death and disability in older adults worldwide with >250,000 deaths/year in US alone

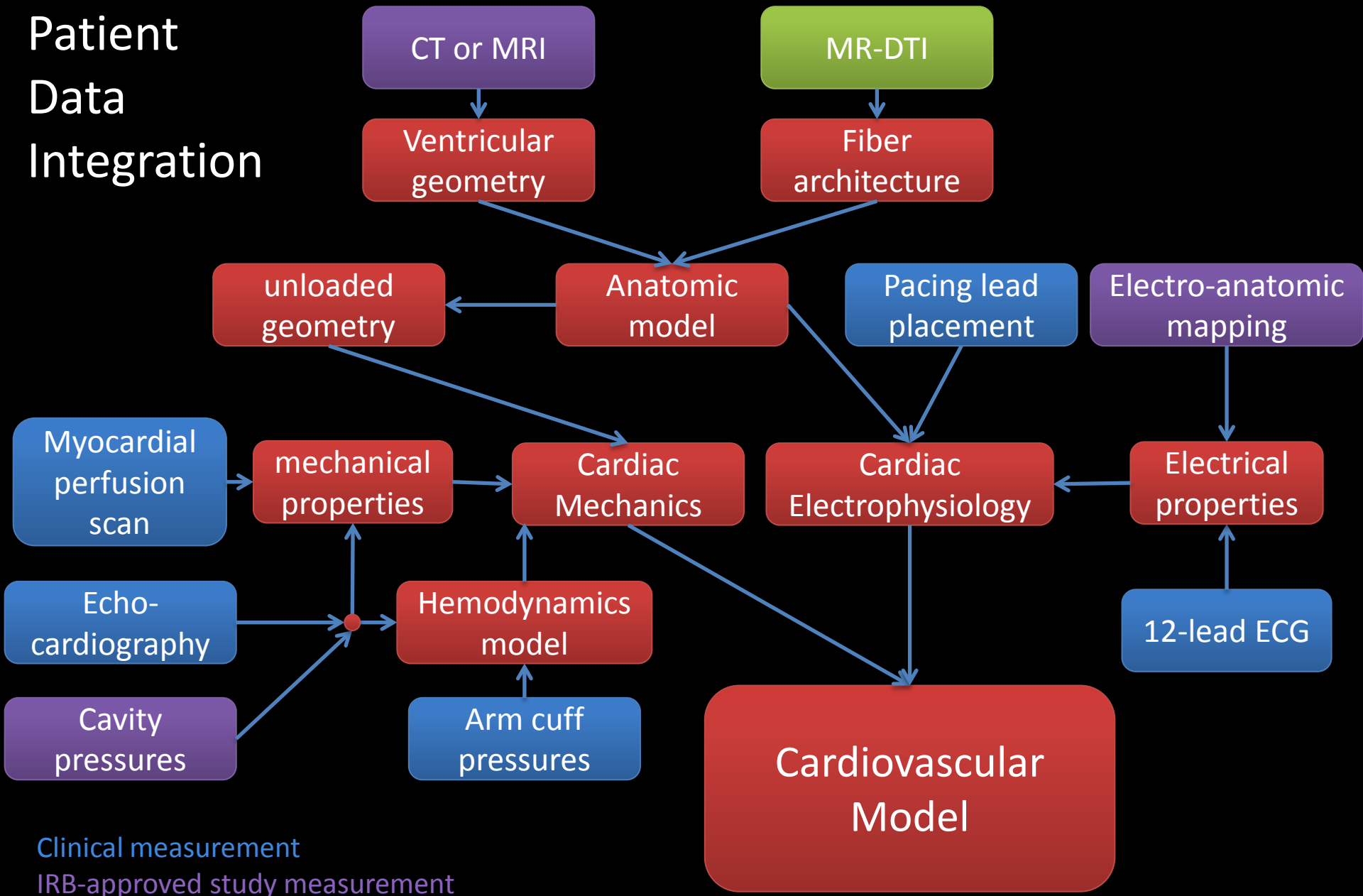
- Cardiac Resynchronization Therapy (CRT) popular treatment of HF patients with dyssynchronous activation

- Apply patient-specific modeling of the cardiovascular system to identify CRT responders and non-responders

Goal

Integrate patient data to create patient-specific models

Patient Data Integration



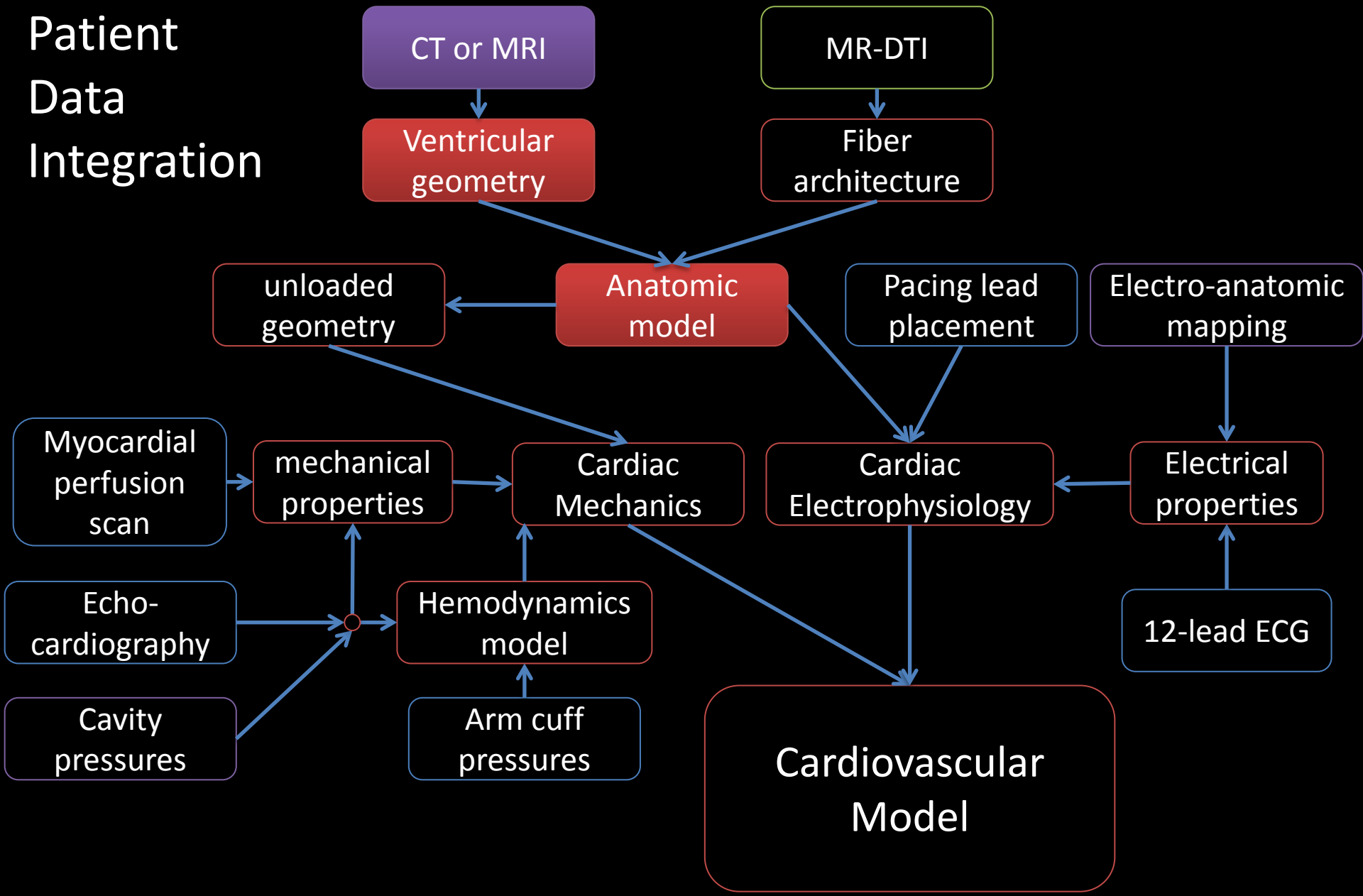
Clinical measurement
IRB-approved study measurement
Non-patient specific measurement
Model or model property

Patient Characteristics

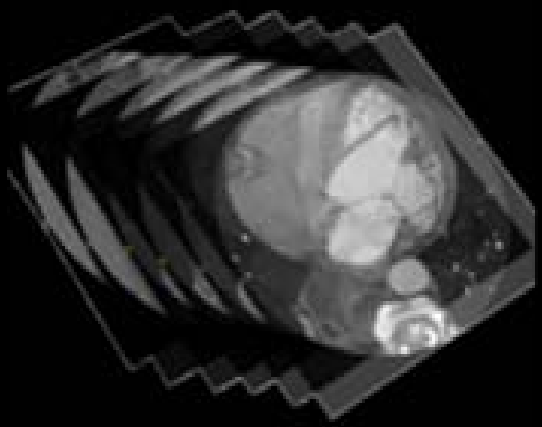
	Patient	Normal or range
Sex	Male	
Age	65	
New York Heart Association HF Class	3	1 - 4 (4 being worst)
QRS width [ms]	148	40 - 120
Ejection Fraction [%]	34	50 - 70
Mitral Regurgitant Fraction [%]	49	0 - 20
Left Ventricular End-diastolic Pressure [mmHg]	23	3 - 12

*Aguado-Sierra et al, Prog Biophys Mol Biol, 2011, in press

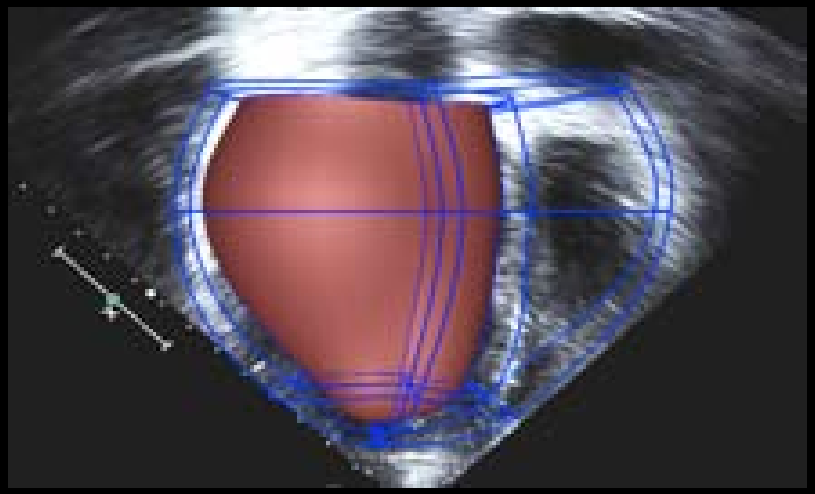
Patient Data Integration



Geometric reconstruction

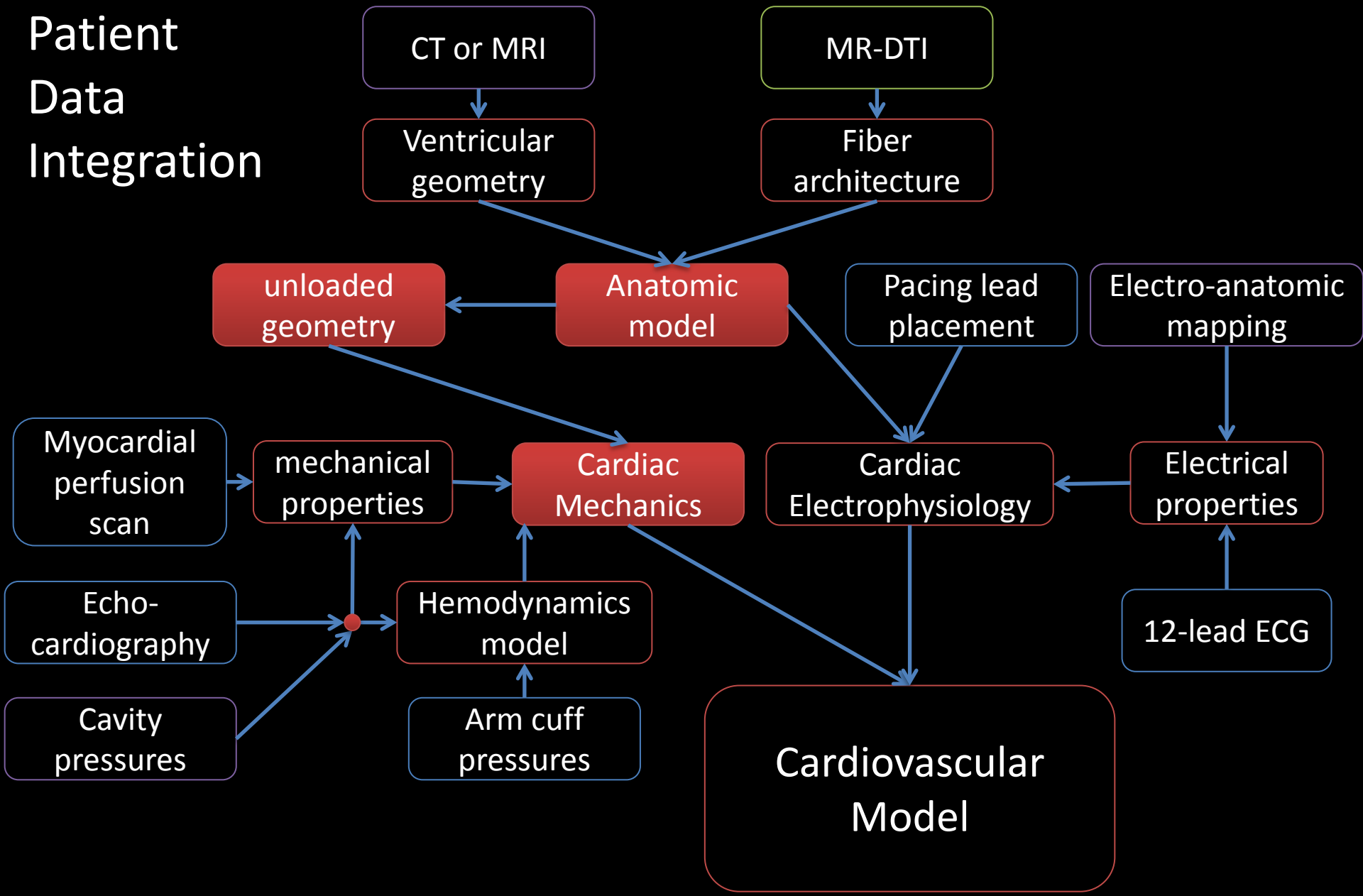


64-slice CT
or
MRI

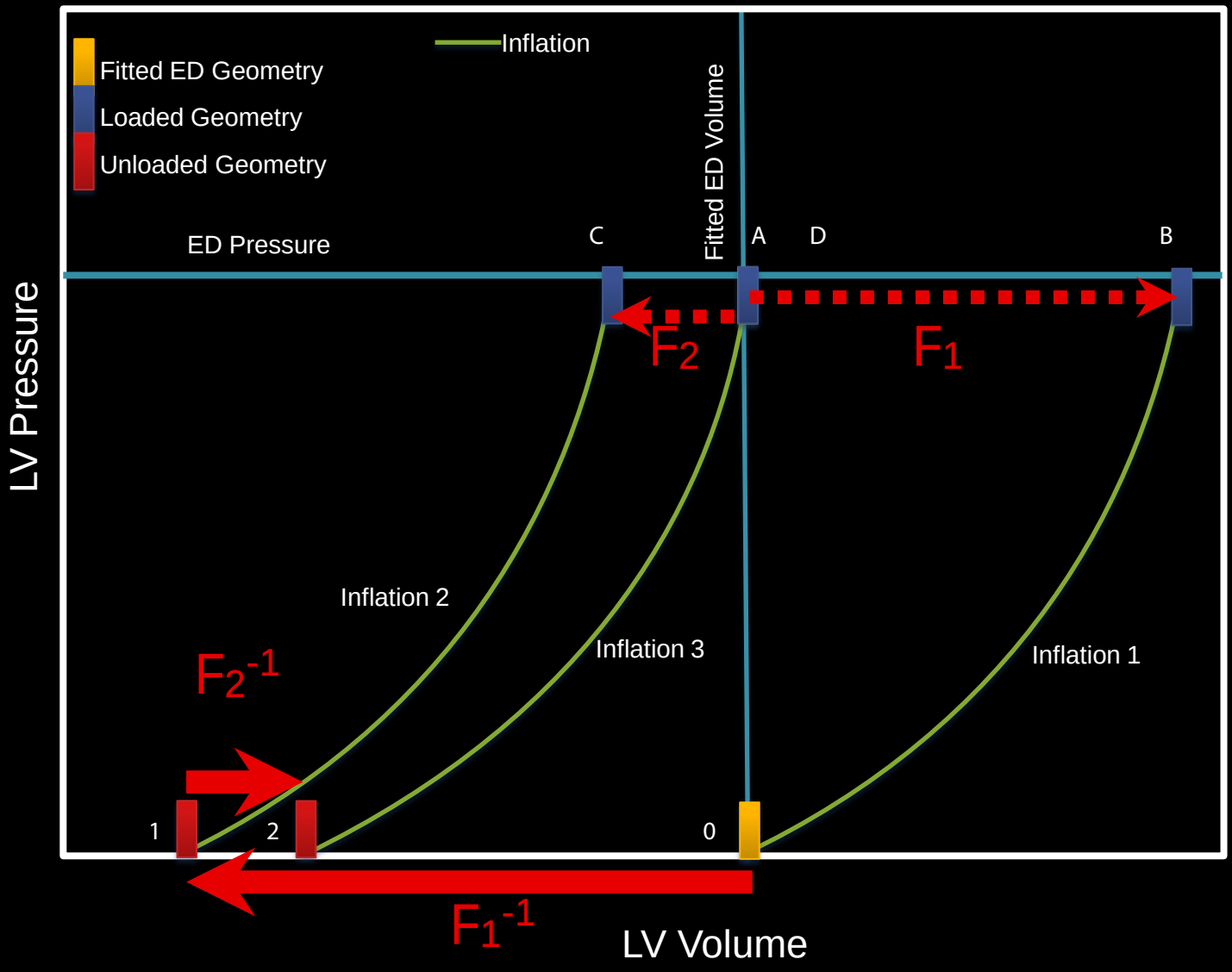


Echo,
2 and 4
Chamber views

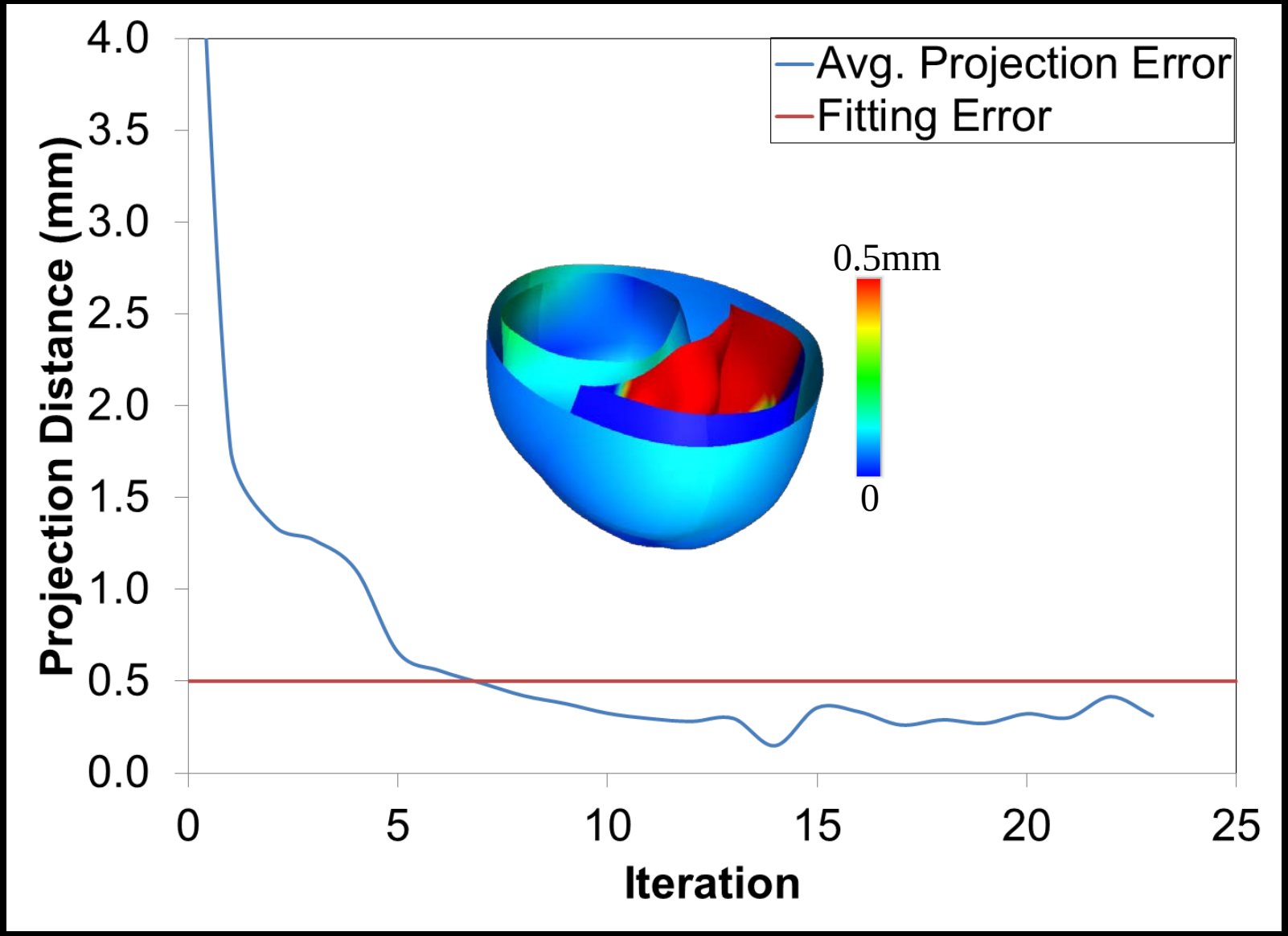
Patient Data Integration



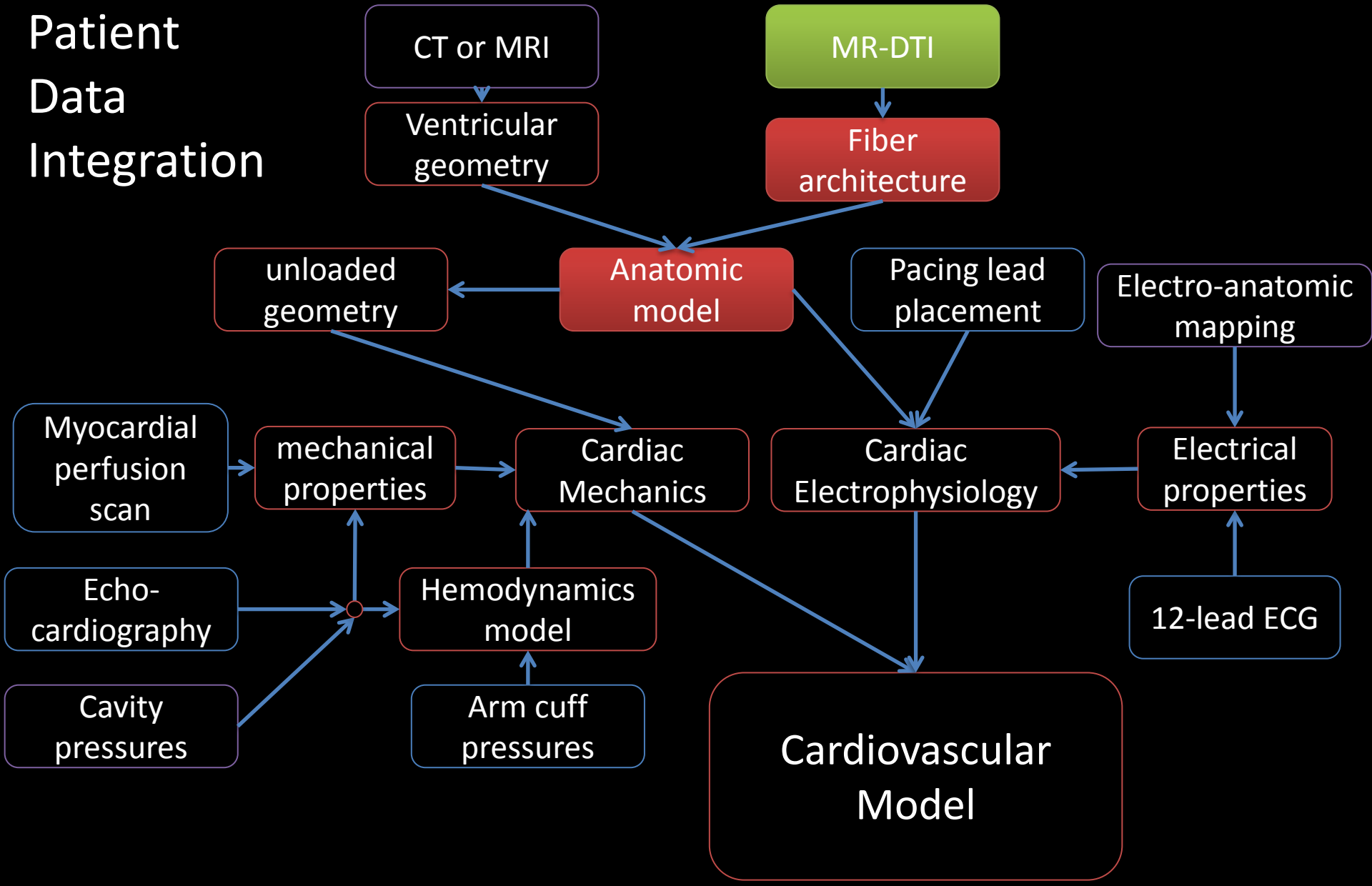
Unloaded ventricular geometry



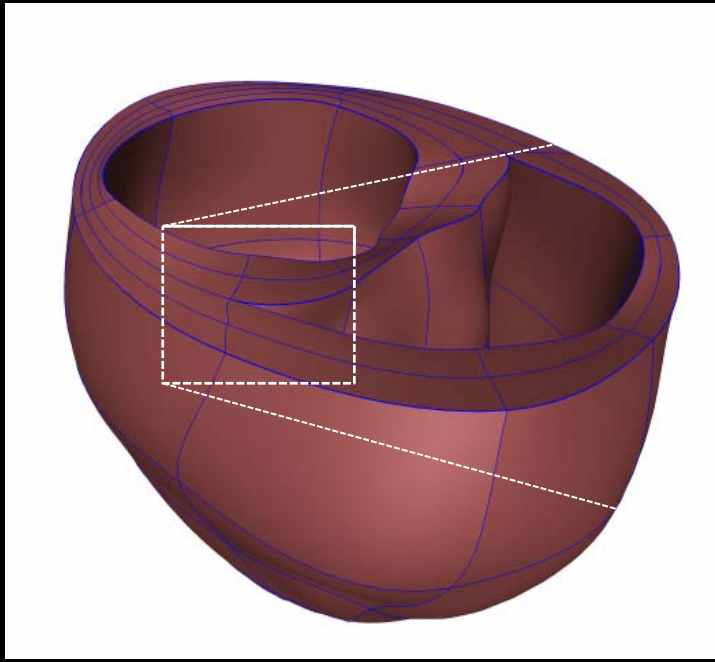
Average Projection Error



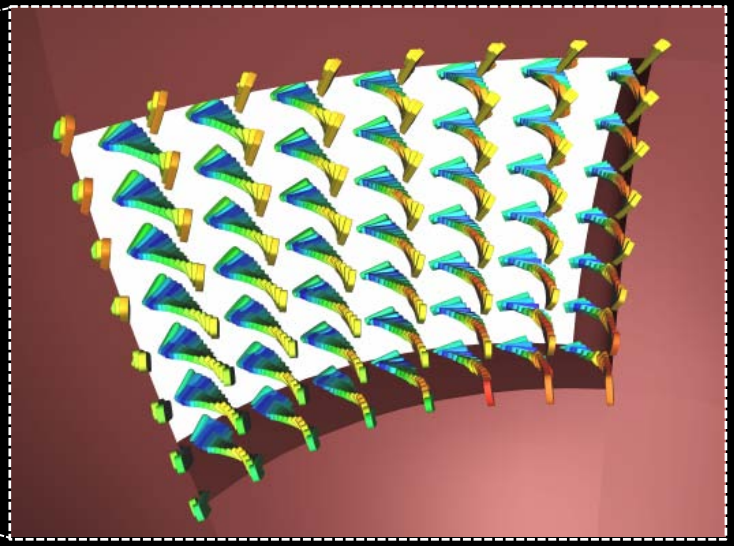
Patient Data Integration



Human Myofiber Architecture

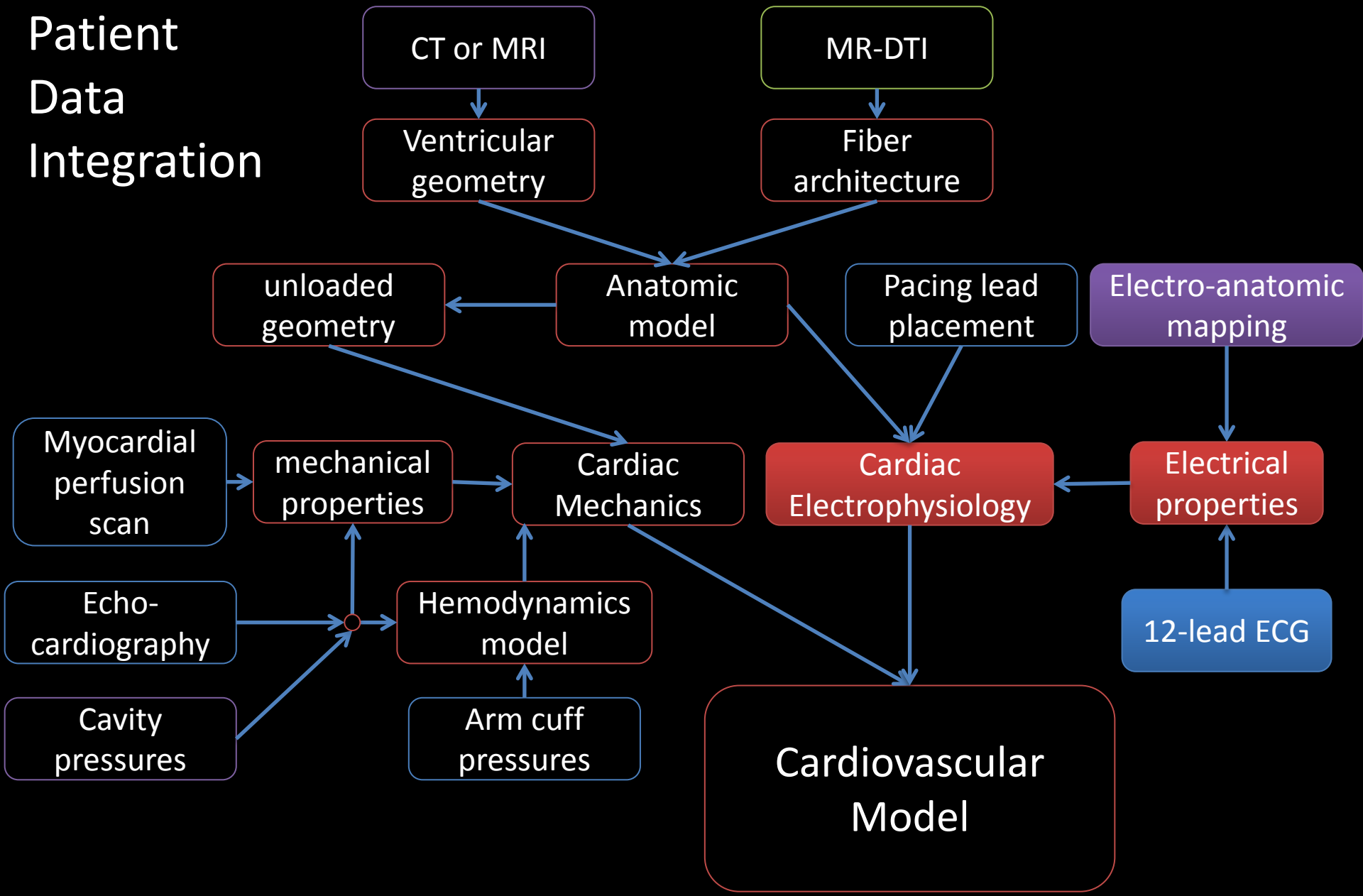


Fitted end-diastolic
3D geometry



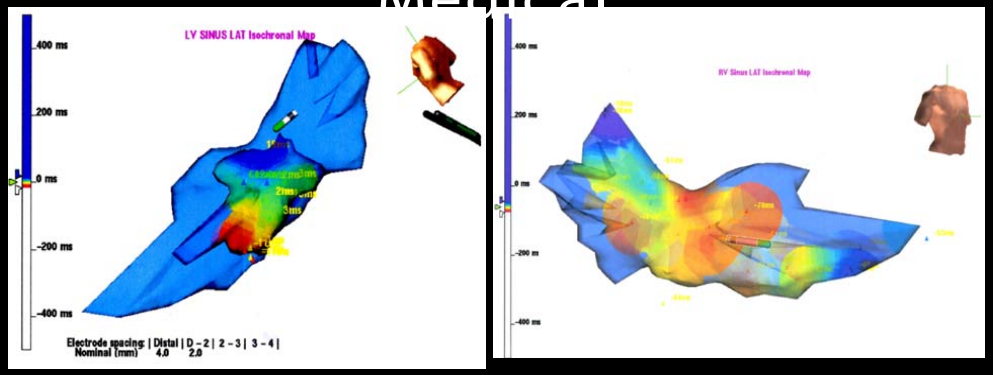
Fiber and sheet structure
reconstructed from DT-MRI

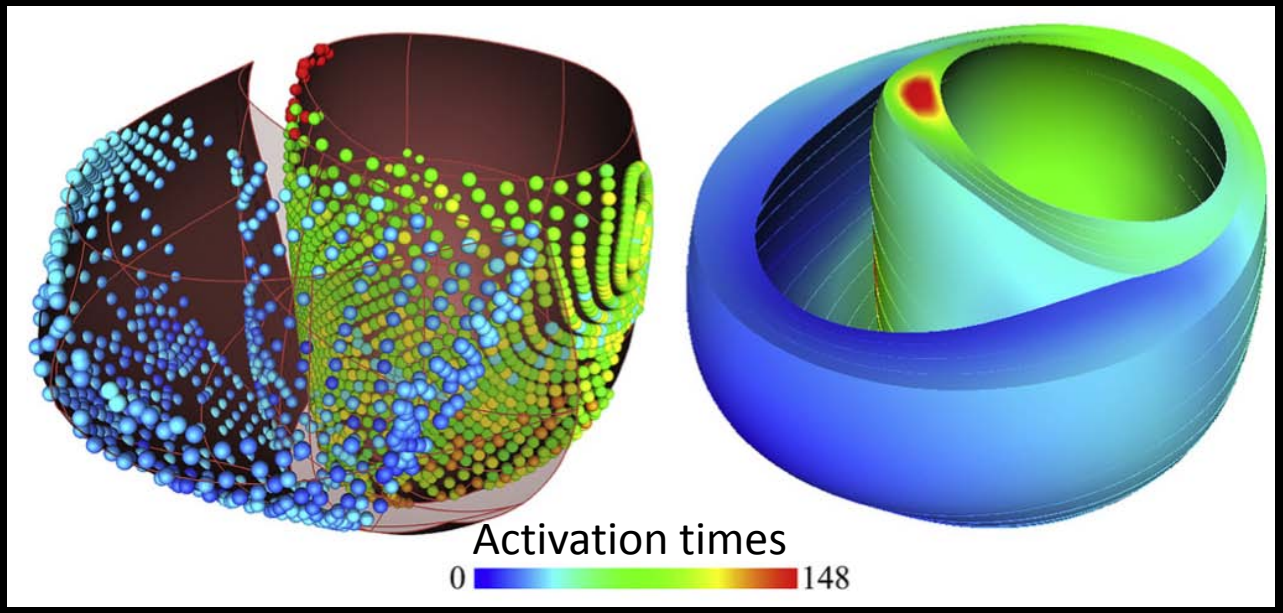
Patient Data Integration



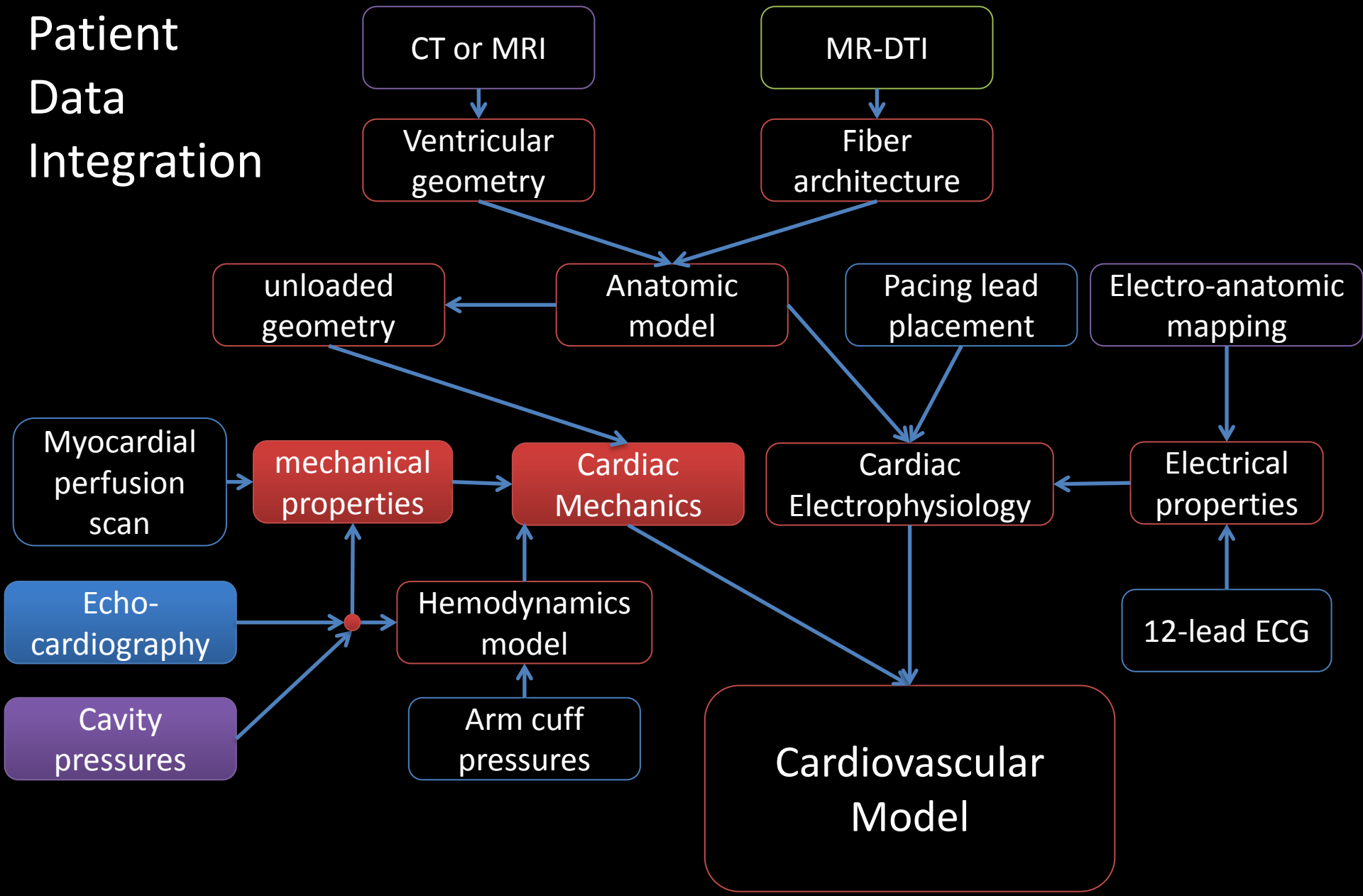
Tissue conductivity

Ensite NavX, St. Jude Medical

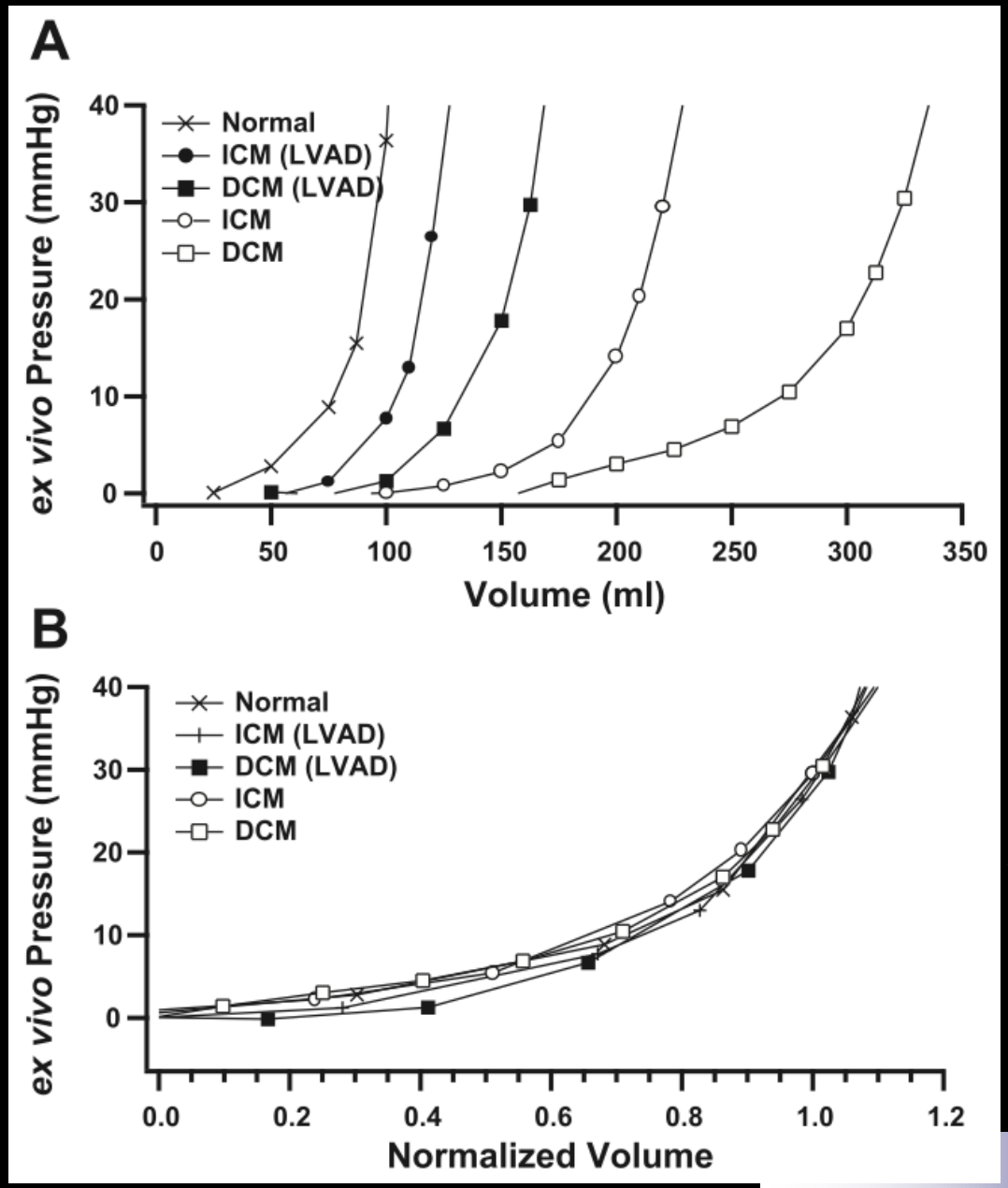




Patient Data Integration



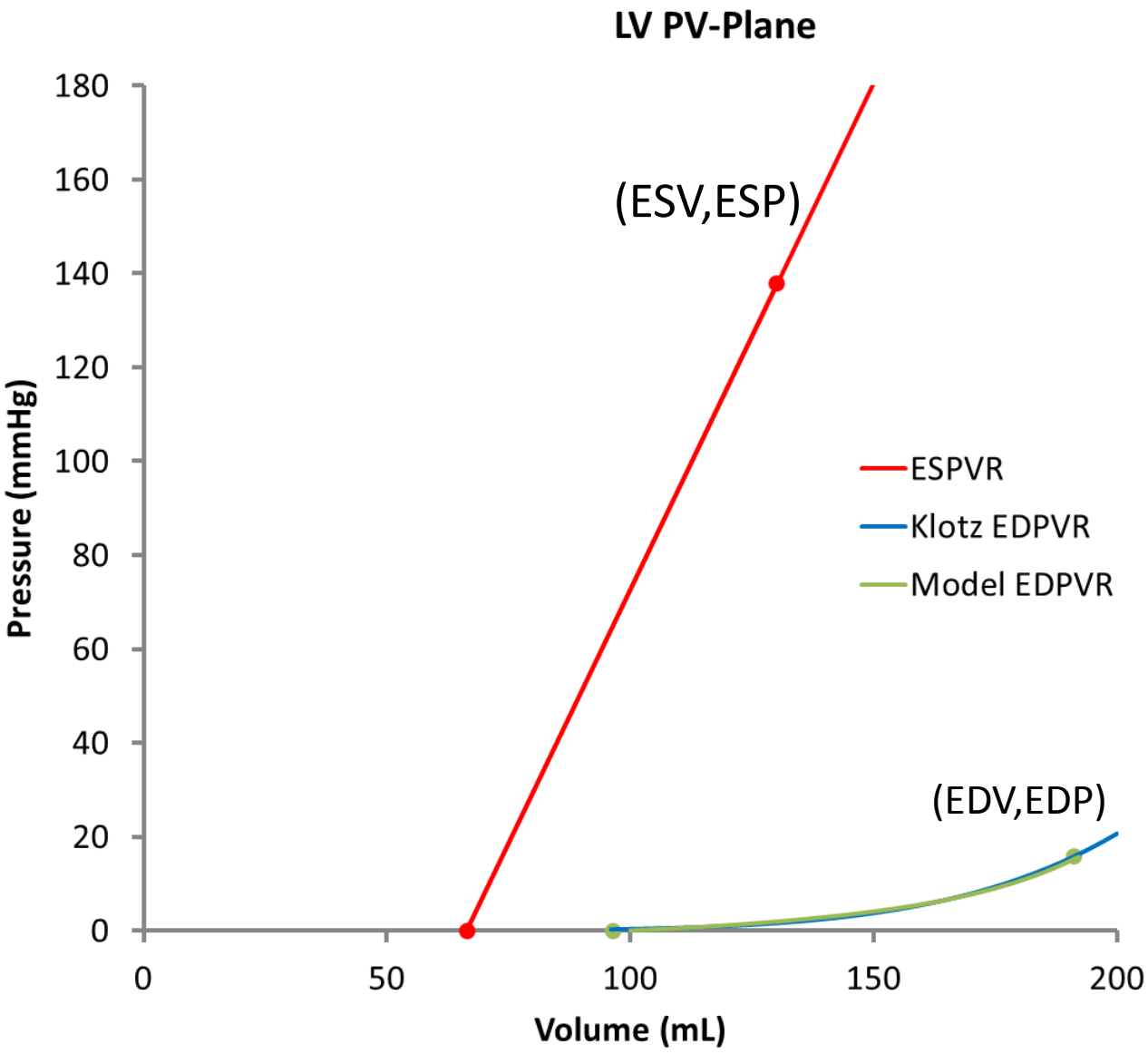
“Klotz curve”: passive properties



Absolute pressure-volume relations

Normalized pressure-volume relations

Mechanical properties



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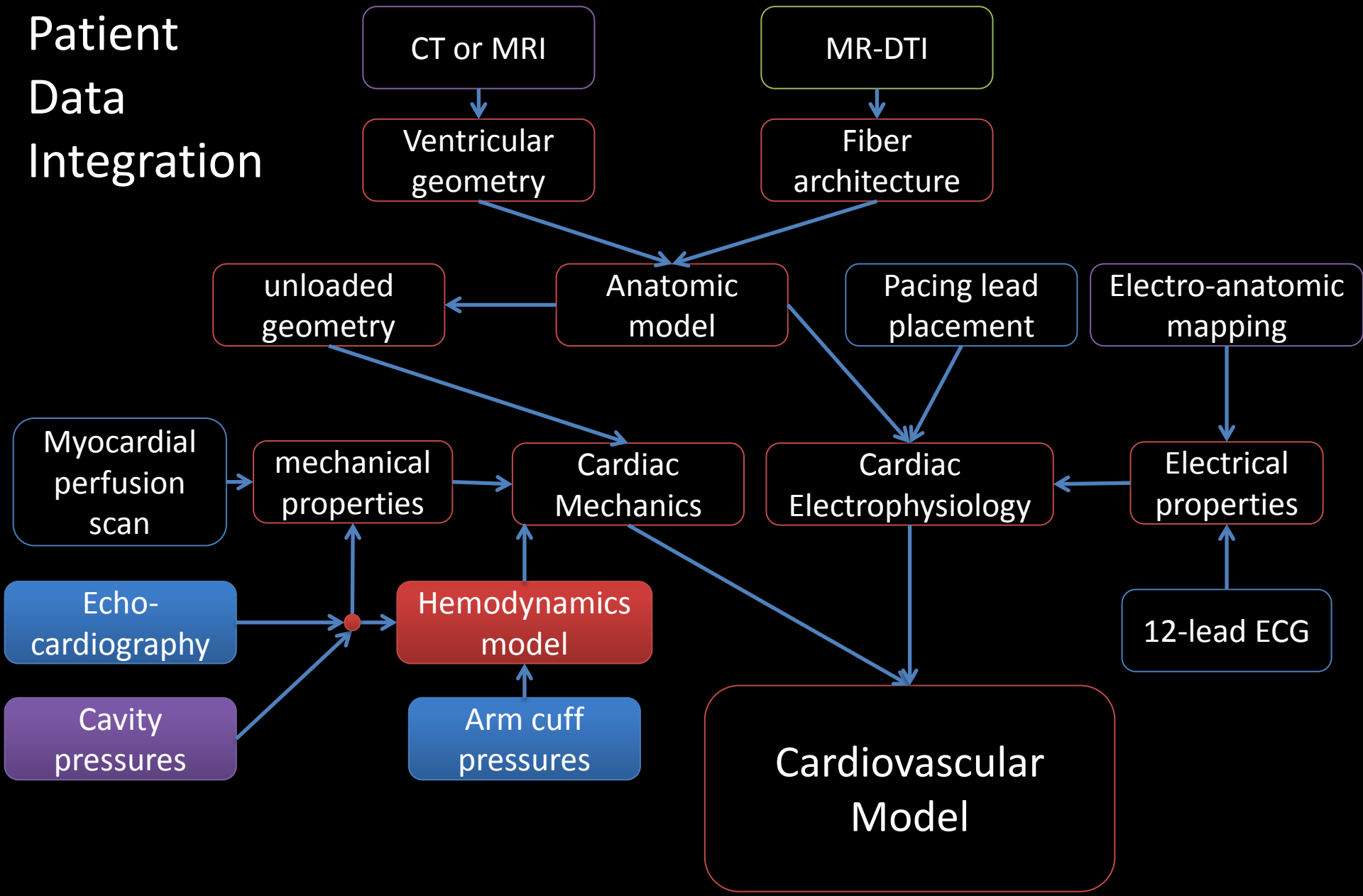
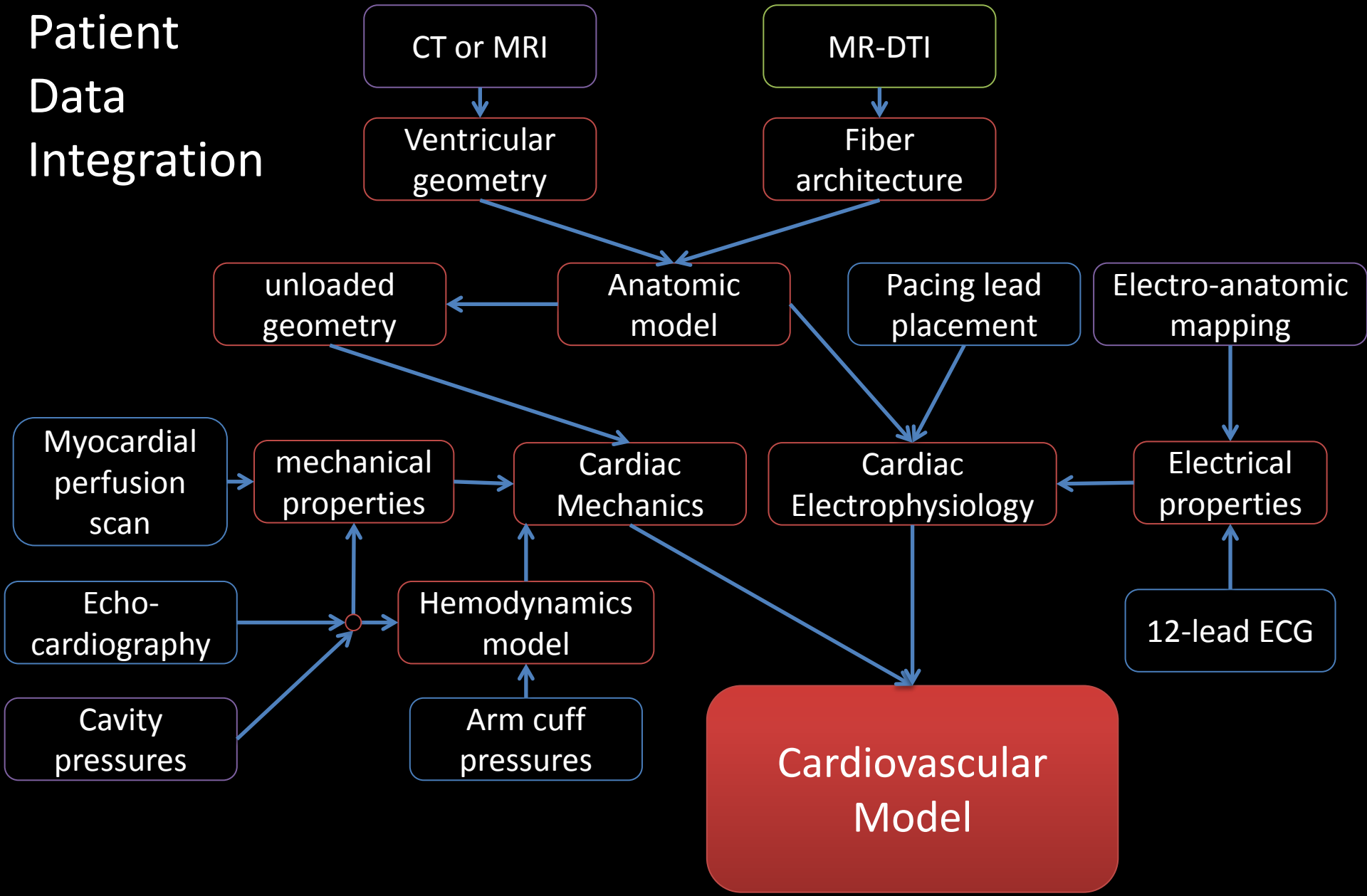


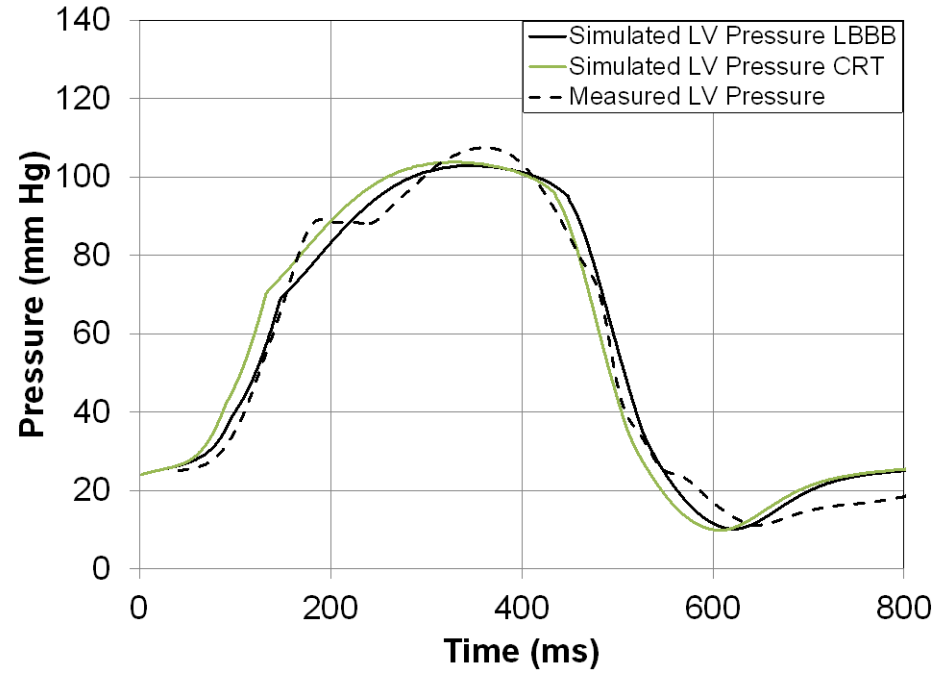
Circulation Properties

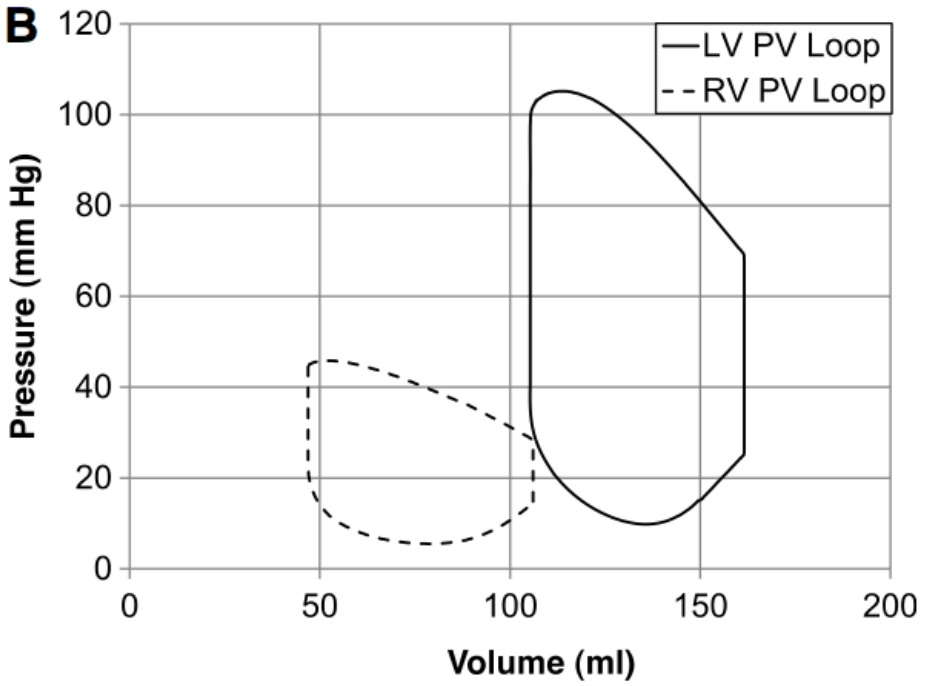
- Obtain from echo and catheterization:
  - valve dimensions
  - cardiac output (CO)
  - mean arterial pressure (MAP)
- Set valve dimensions, CO and MAP in Lumped systems model of circulation
- Run FE model coupled to circulation, let remaining parameters be calculated by adaptation rules (CircAdapt model)

Patient Data Integration



Results: Global hemodynamics

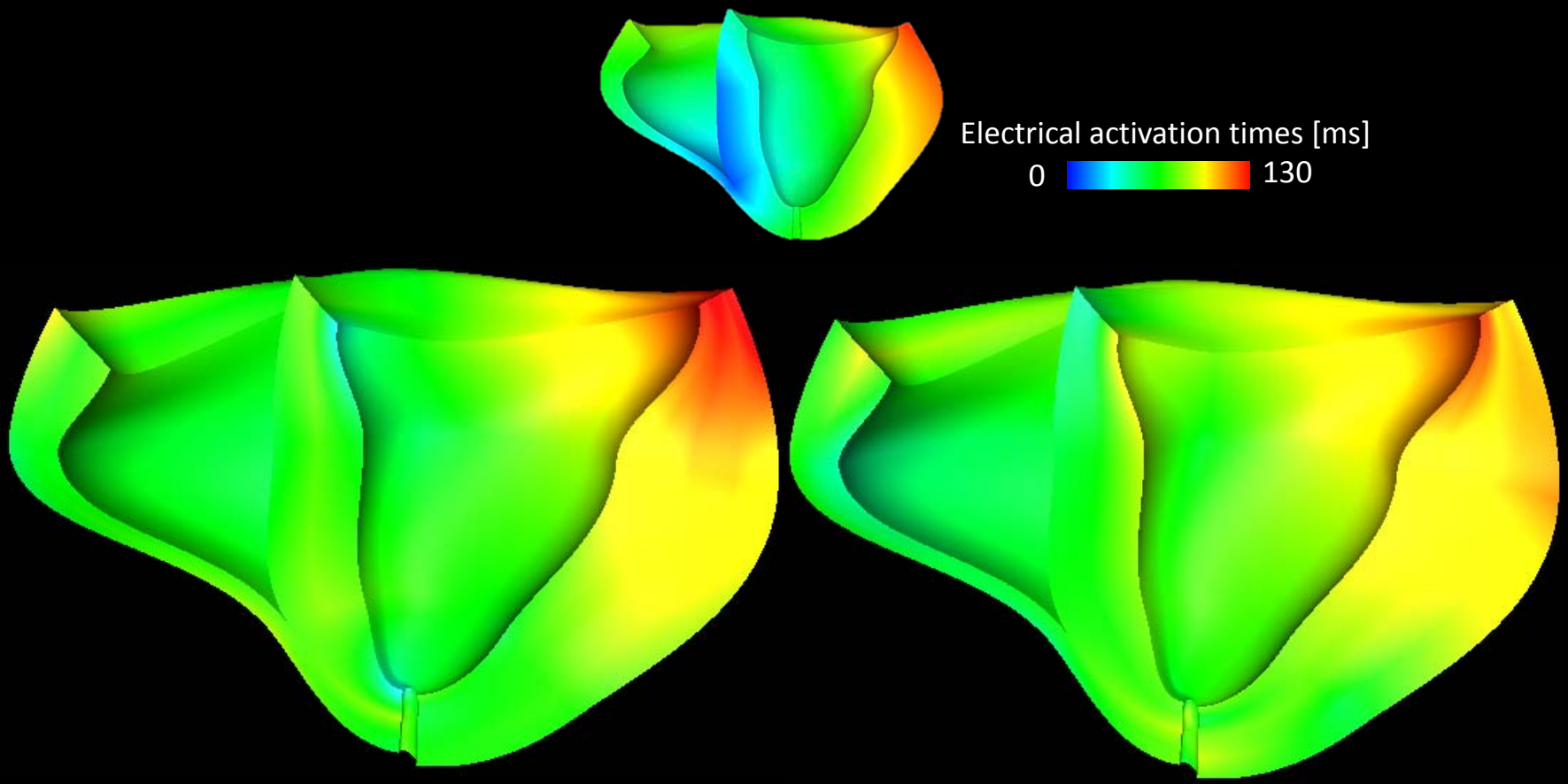




Results: Fiber strain

Models of Growth and Remodeling

Asymmetric growth after 2 months of RV pacing



Acknowledgments

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