Multi-modal Pipeline for Comprehensive Validation of Mitral Valve Geometry and Functional Computational Models

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Motivation

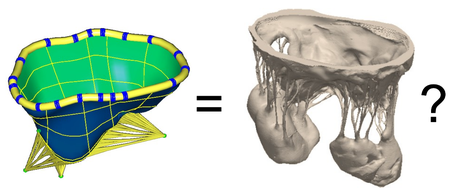
Mitral Valve (MV) Regurgitation

- Most common form of valvular heart disease
- Significant mortality & morbidity rates
- Traditional treatment: MV ***replacement***

MV Repair [1]

- Better preservation of heart function & long-term survival
- Requires experienced surgeon & pre-operative planning
  - ➔ Efficient training/planning tools to optimize intervention outcome
  - ➔ Development of computational MV models
  - ➔ Models remain simplifications

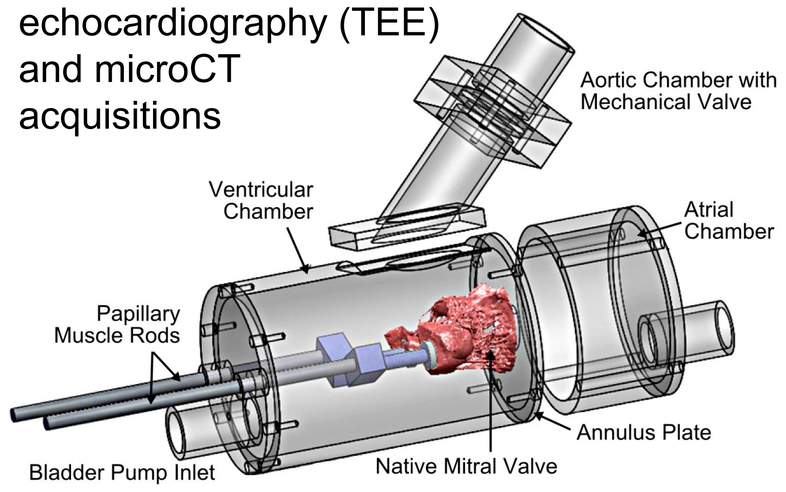
➔ **Assess clinical applicability of models by validation against comprehensive ex-vivo data**

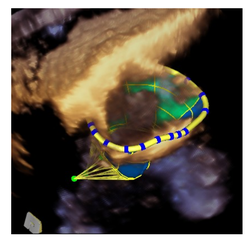


Data Acquisition

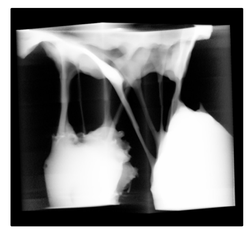
Mechanical Simulator

- In-vitro closed-loop left heart simulator [2]
- Design optimized to allow for echocardiography (TEE) and microCT acquisitions





TEE

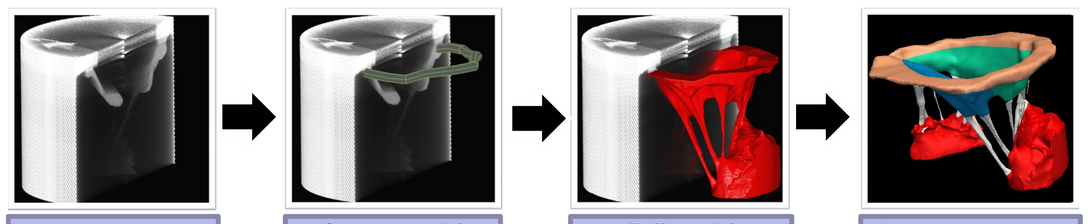


microCT

Ex-Vivo MicroCT

High-Fidelity Model

- Identify annulus and papillary muscle locations
  - ➔ Seed points for Random Walker segmentation
- Convert mask to mesh
  - ➔ Marching Cubes
- Segment chordae tendineae
  - ➔ Novel path tracing approach



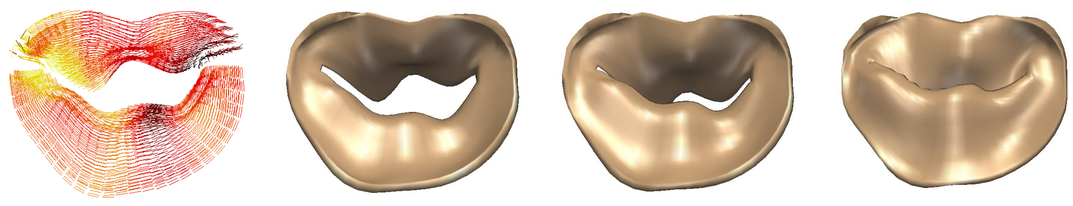
Model Extraction

State-of-the-Art Geometrical Model [3]

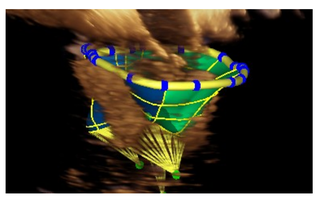
- Physiological point distribution model
- Based on 9 anatomical landmarks
- Marginal Space Learning framework

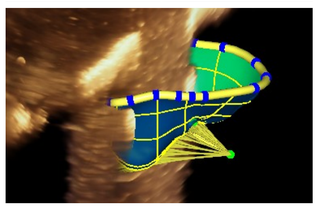
Biomechanical Modeling [4]

- Transverse isotropic linear elasticity
- Co-rotational finite elements method



In-Vivo TEE





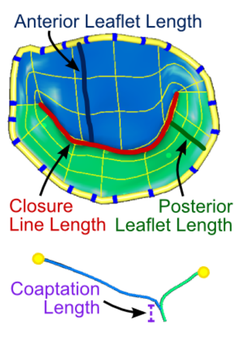
Model Validation

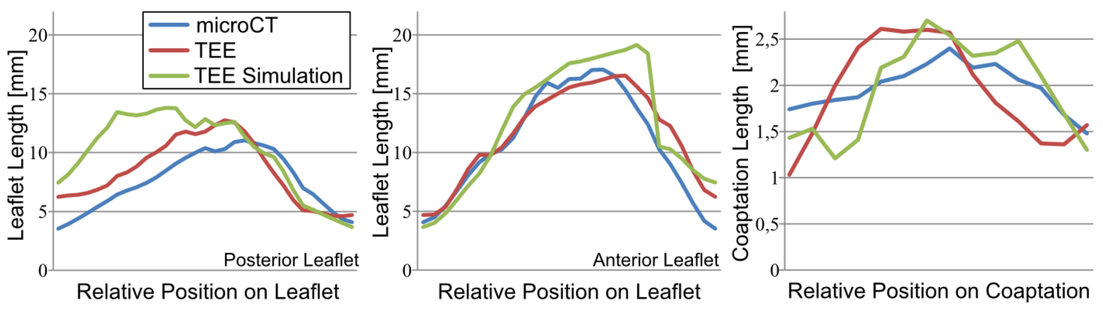
Geometric Comparison of Anatomical Models

- TEE model vs. microCT model
- MV excised from ovine heart
- Measured clinically-related parameters

MV Closure Computation (Biomechanics)

- Based on end-diastolic TEE model
- Pressure profile: 0 *mmHg* to 120 *mmHg*





Conclusion

Contributions

- Novel **complete model validation pipeline**
- **Bridge** between ex-vivo and clinical modalities
- Integration of **geometric** and **functional** models
- **Controlled** setup to acquire images from invasive and non-invasive modalities at almost identical conditions
- Robust algorithms to extract **reproducible** models
- First experiments on real data
  - ➔ Utilized TEE model can accurately represent important biomarkers

Future Work

- Experiments on more specimen
- Evaluation of prediction power of current and future in-vivo computational frameworks

References

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