A Computational Framework for Patient-Specific Biomechanical Evaluation of SAVR and TAVR

- A potential strategy to determine the best intervention for younger patients with AS

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Disclosures

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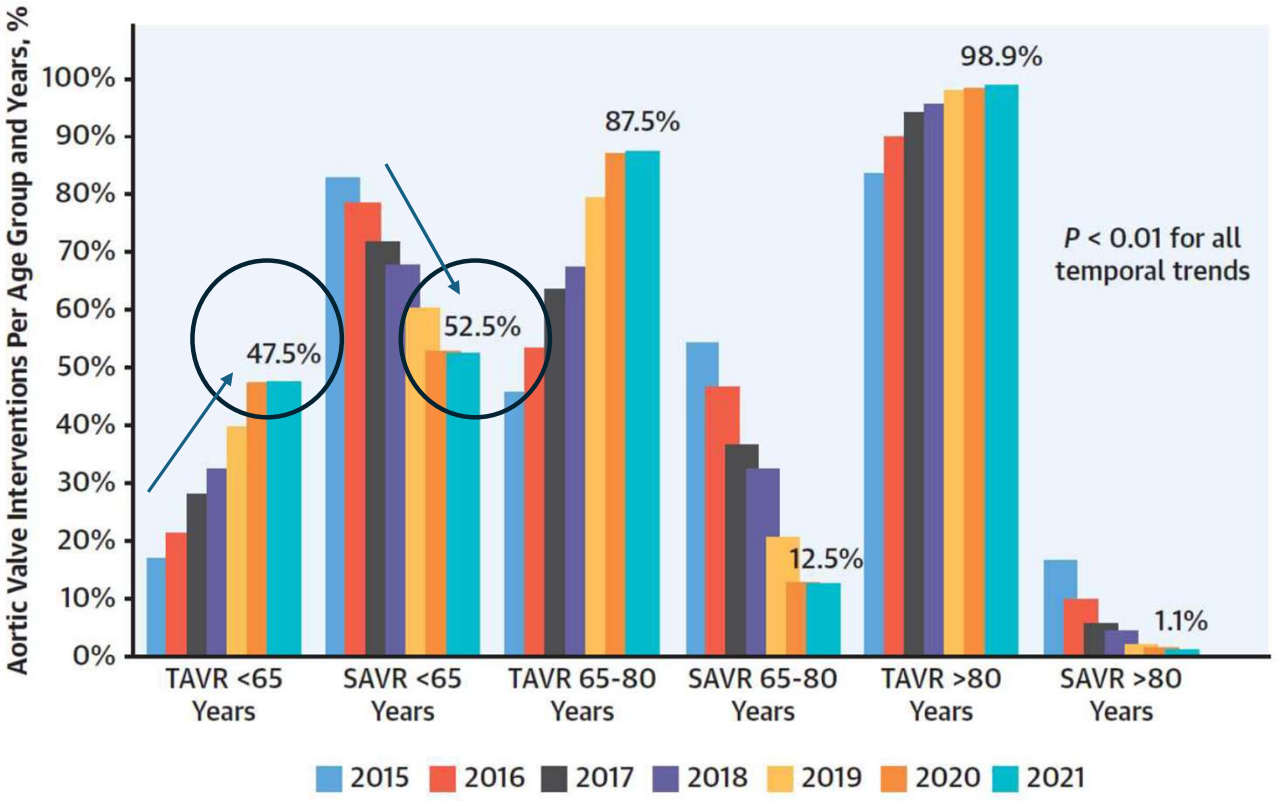
A Novel Computational Approach To Optimize Fontan And Improve Surgical Predictability

High-performance computational approach to improve cardiac interventional predictability

(In-kind) HPC resources to support above research projects

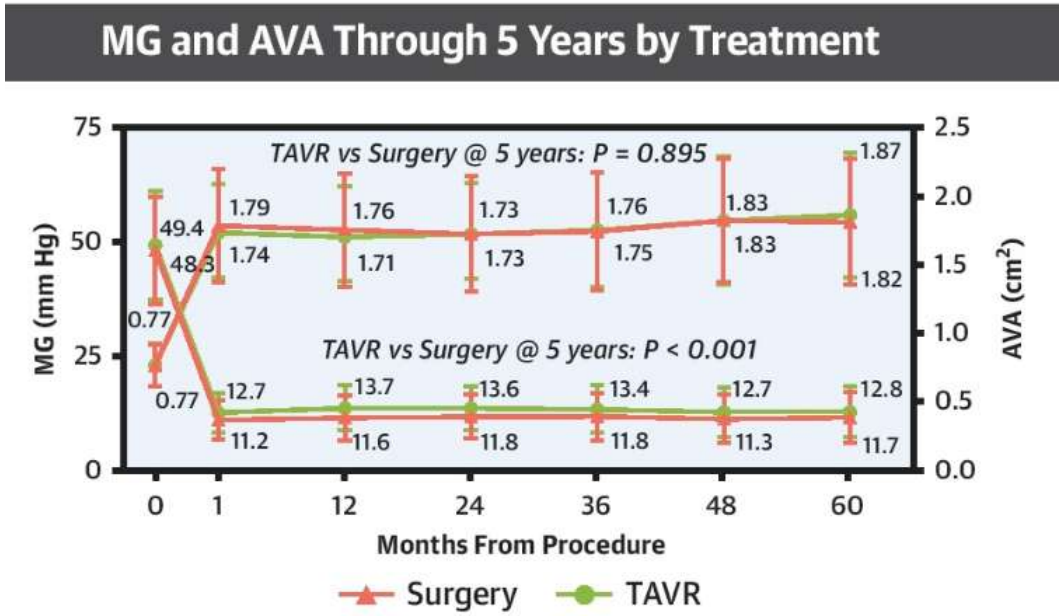
Evaluation of flow dynamics in a novel Transcatheter Pulmonary Valve – Phase II

TAVR's Expanding Role: Increasing Use in Younger Patients



JACC. 2022 Nov 22;80(21):2054-6

Can we predict the most optimal intervention for a patient?



Similar and stable valve hemodynamics were observed for both groups with higher MG for TAVR

Hahn, R et al., J Am Coll Cardiol Img.(2025)

JAMA Cardiology | Original Investigation

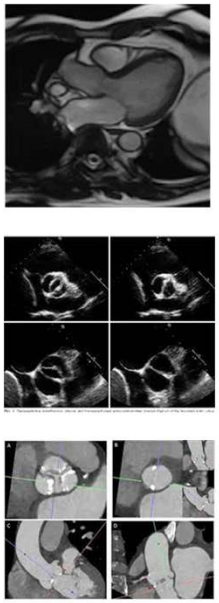
Outcomes of Balloon-Expandable Transcatheter Aortic Valve Replacement in Younger Patients in the Low-Risk Era

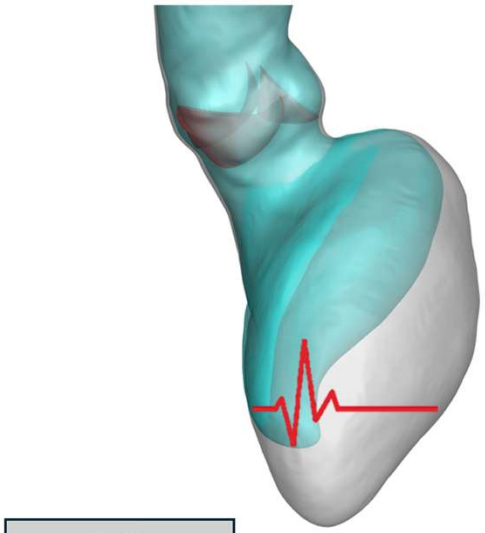
Megan Coylewright, MD, MPH; Kendra J. Grubb, MD, MHA; Suzanne V. Arnold, MD, MHA; Wayne Batchelor, MD, MHS; Abhijeet Dhoble, MD, MPH; Aaron Horne Jr, MD, MBA, MHS; Martin B. Leon, MD; Vinod Thourani, MD; Tamim M. Nazif, MD; Brian R. Lindman, MD, MSc; Molly Szerlip, MD

Patients < 65 years undergoing TAVR are at higher risk with greater likelihood of reduced longevity

Physiologically realistic virtual intervention to <u>quantitatively predict</u> patient's post-operative valve function

Patient Data



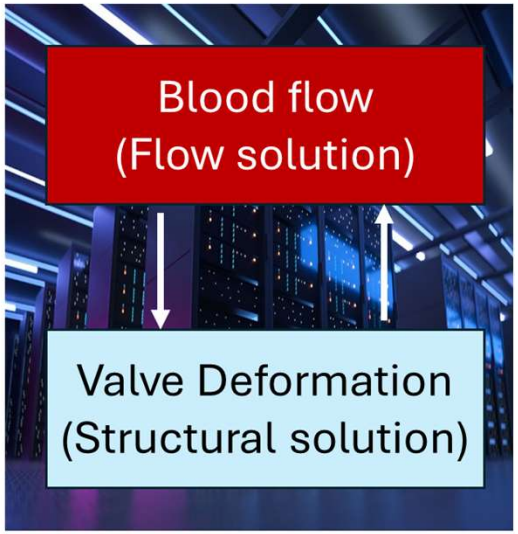


EDV

Model Predicted ESV tuned to HR

+

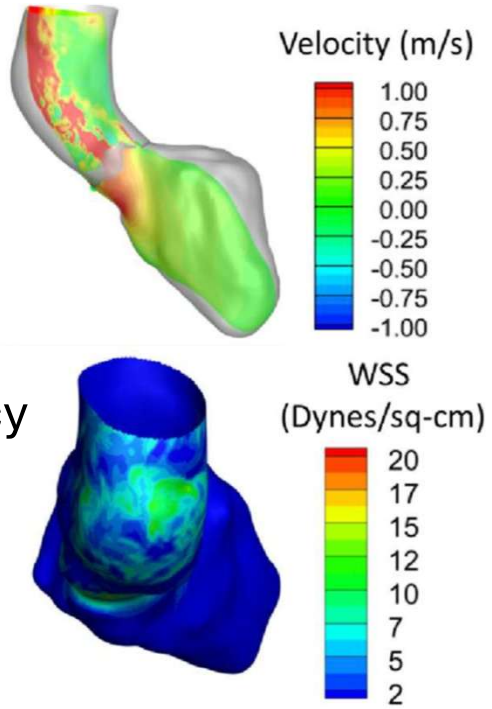
Fluid-Structure Interaction (FSI) Modeling



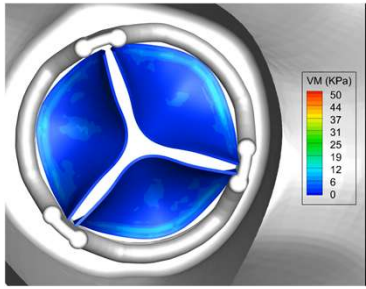
V. Govindarajan et al RSOS 9, no. 2 (2022): 211694; V. Govindarajan Ann Biomed Engg. 52, no. 2 (2024): 414-424; V. Govindarajan et al *Biomech Model Mechan* (2024): 1-11.

Virtual Intervention can improve predictability

- Evaluate Biomechanical Performance of Valve Replacement Options (TAVR vs. SAVR):
  - Aortic hemodynamics and stresses
  - valve function
  - valve durability (valve stresses)
- Refinement to maximize hemodynamic efficiency
- Robustness of the intervention across different flow conditions

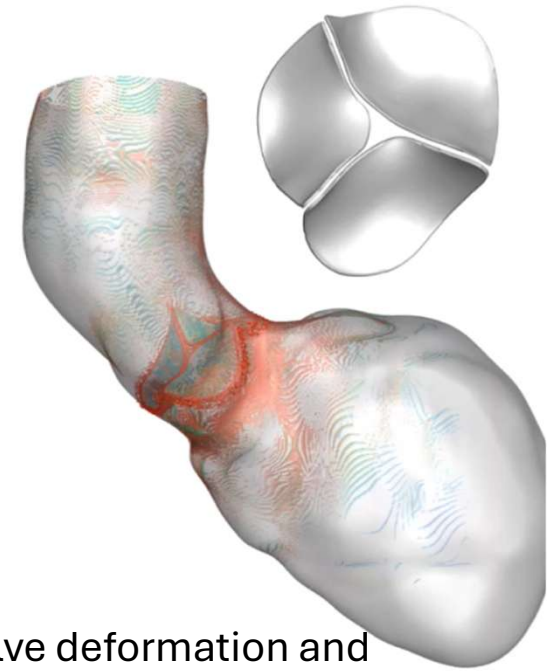


Valve Stresses



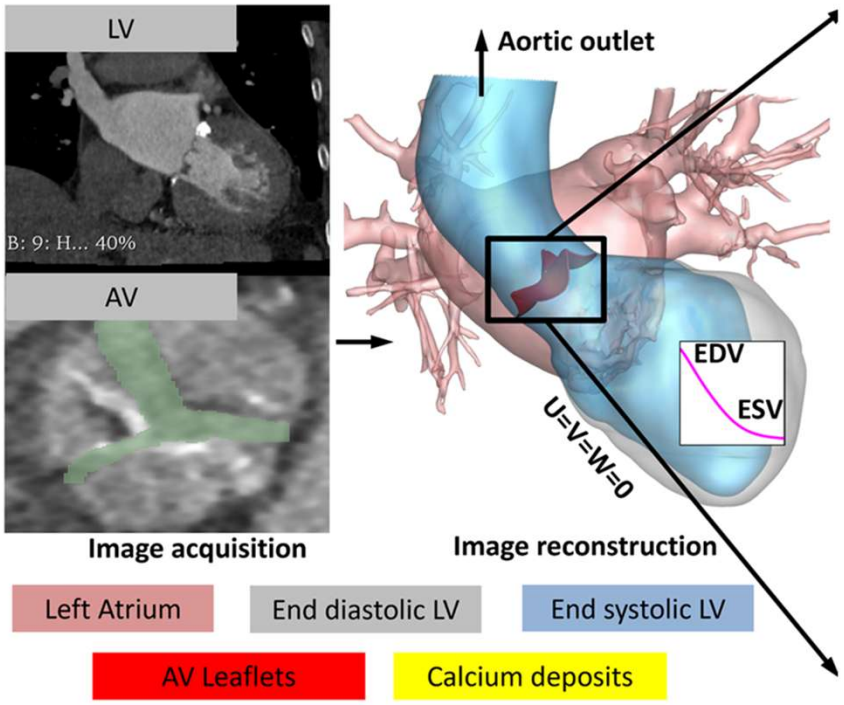
Virtual SAVR vs. TAVR and their comparison with Normal AV

Normalized AV

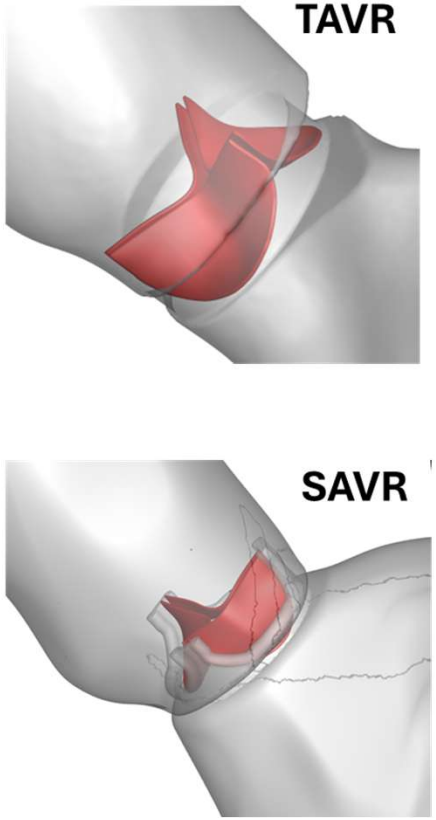


Valve deformation and aortic hemodynamics

70-year-old Female with AS → 23 mm TAVR

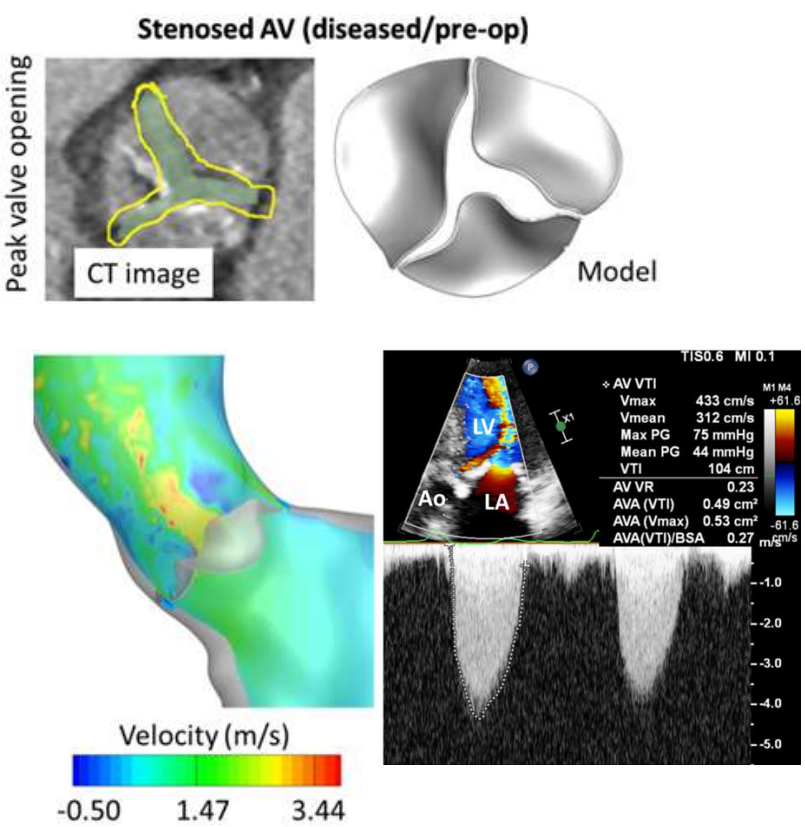


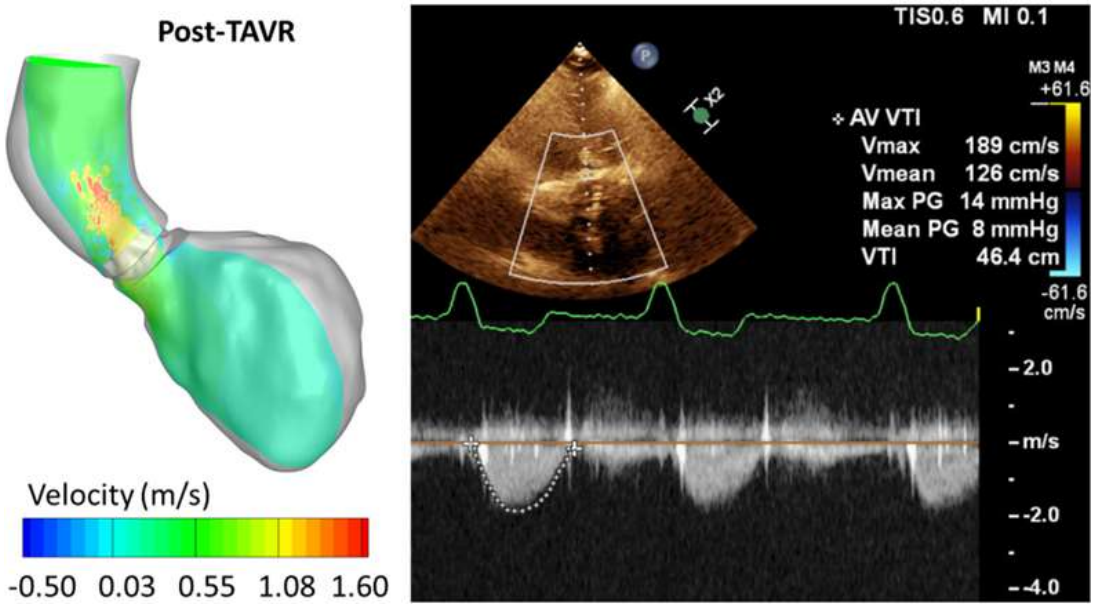
Virtual Surgery



Note: Calcification was virtually removed to derive the normalized AV (NAV) model

Model predictions of pre- and post-TAVR were validated with clinical data

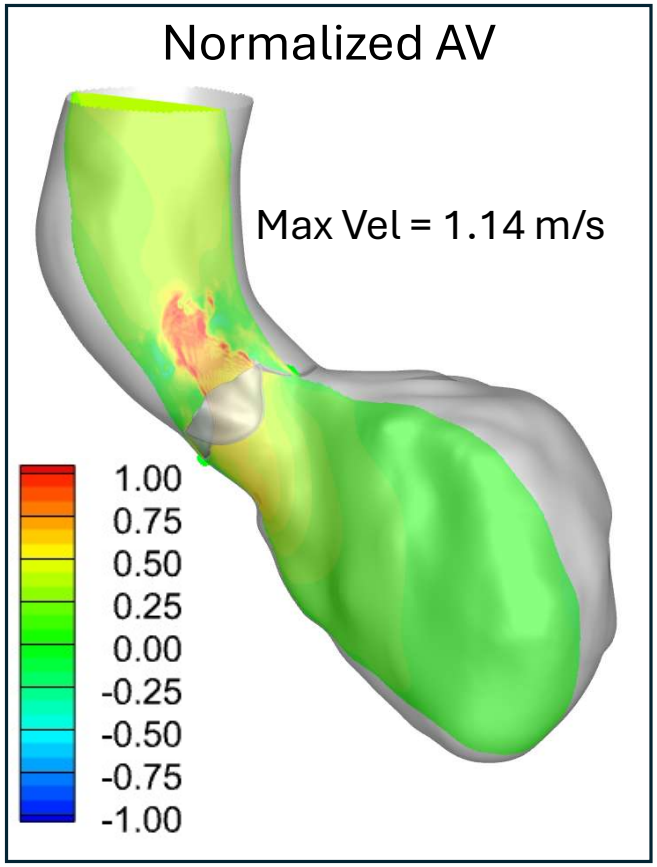


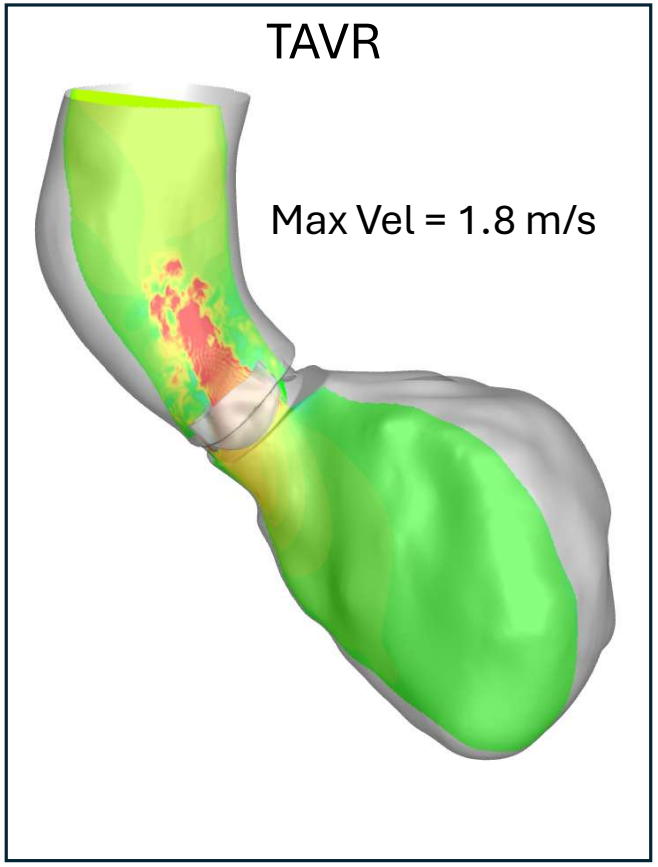


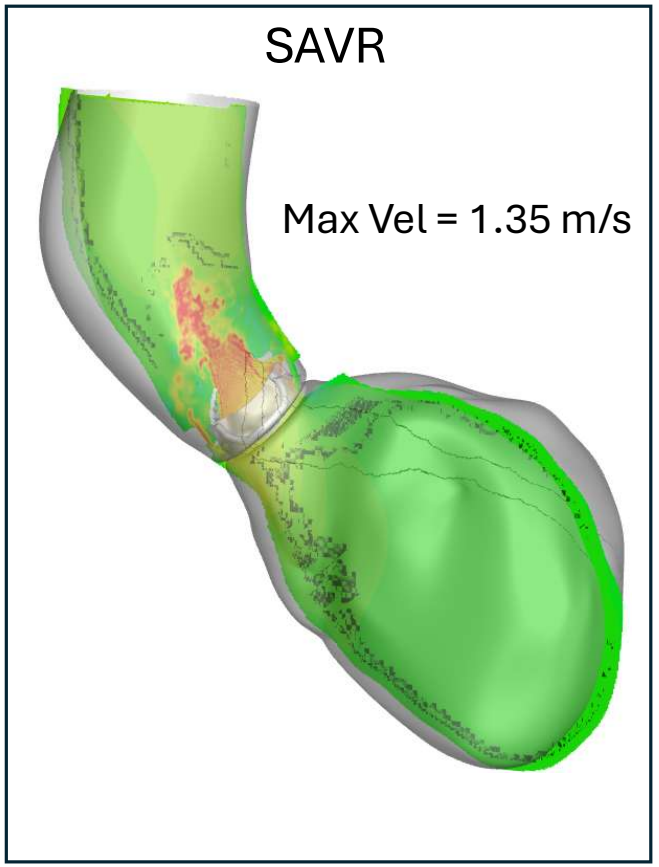
Pre- and post-op model predictions were consistent with clinical data

V. Govindarajan et al RSOS 9, no. 2 (2022): 211694

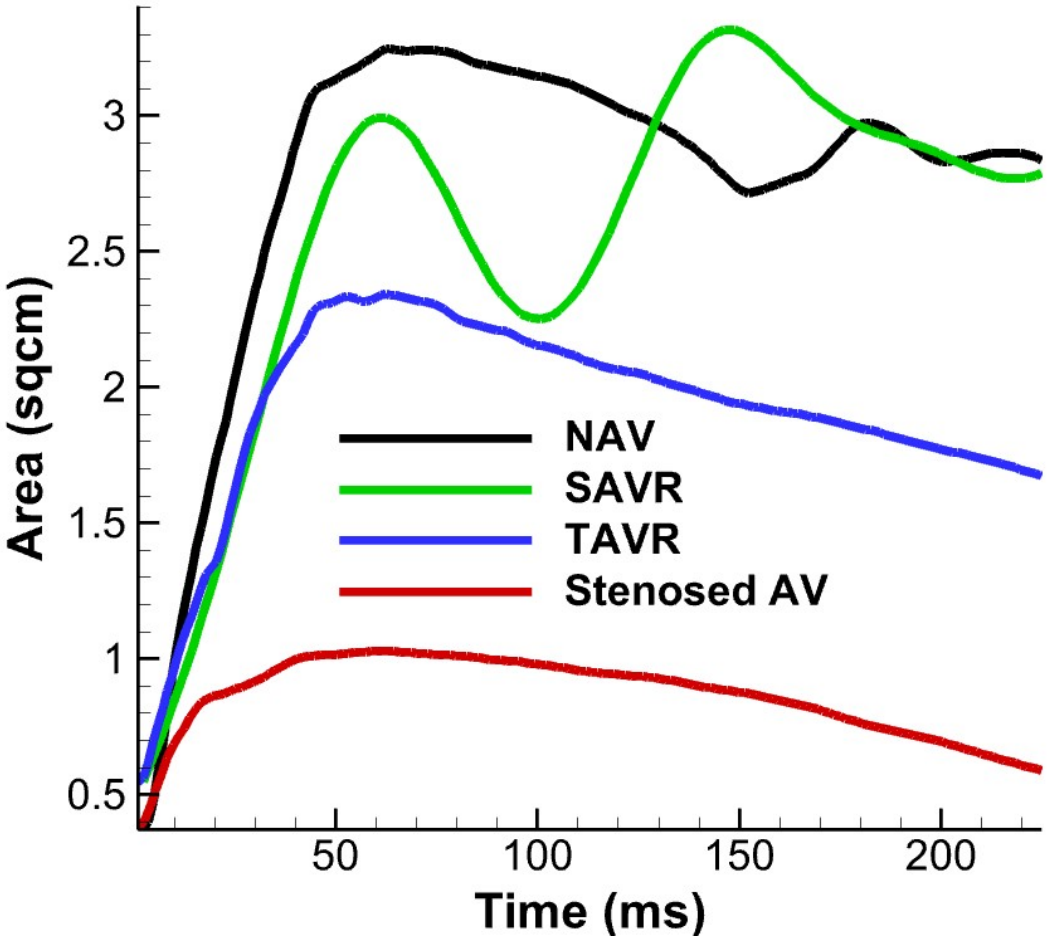
Aortic hemodynamics: TAVR vs SAVR Comparison with NAV

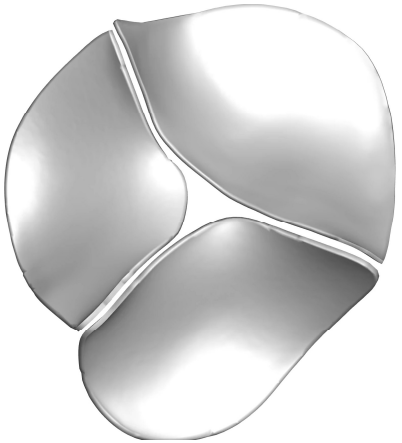






Opening dynamics: TAVR vs SAVR- comparison with Normalized AV





Normal AV

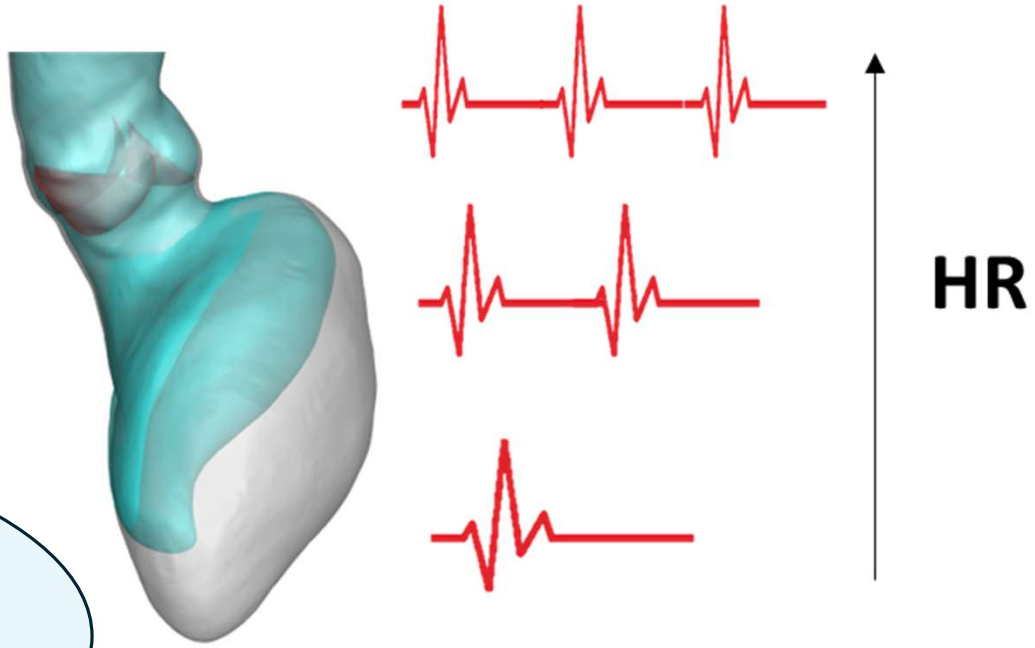
TAVR

SAVR

Virtual Stress Testing can Reveal the Impact of Multi-Physiologic Flow on Valve Performance

Exercise/Dobutamine - based stress test

FSI-based virtual stress test

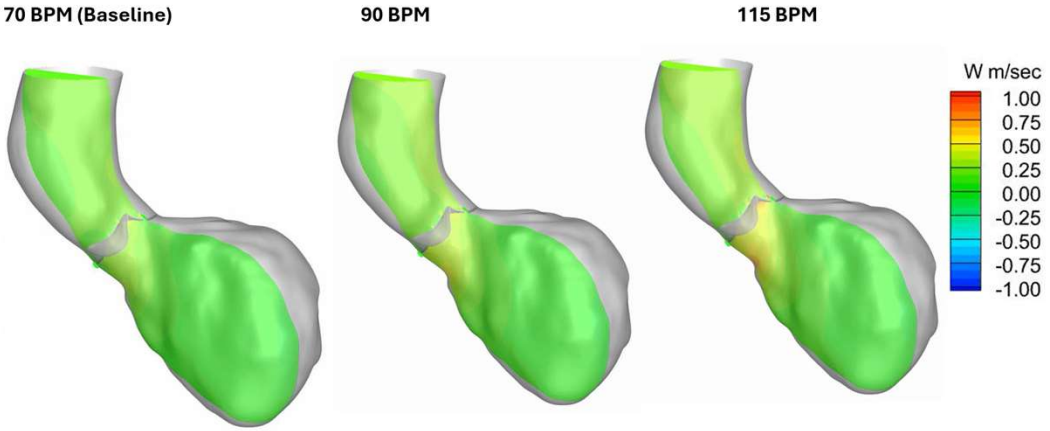


Velocity
ΔP
AVA

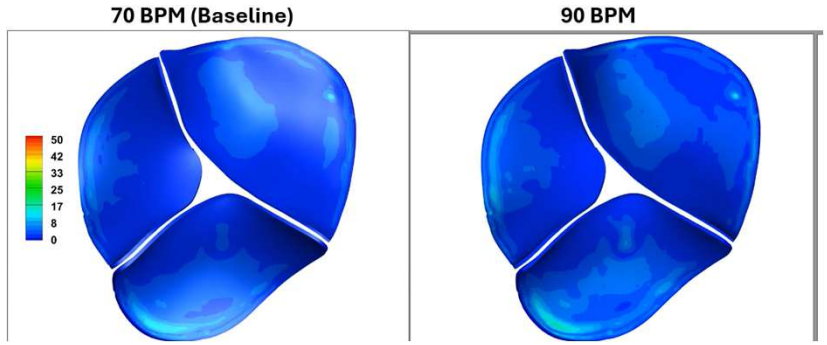
Energy loss
Valve stresses
Aortic wall shear stress
LV Pressure

FSI-based Virtual stress test of Normal Aortic Valves

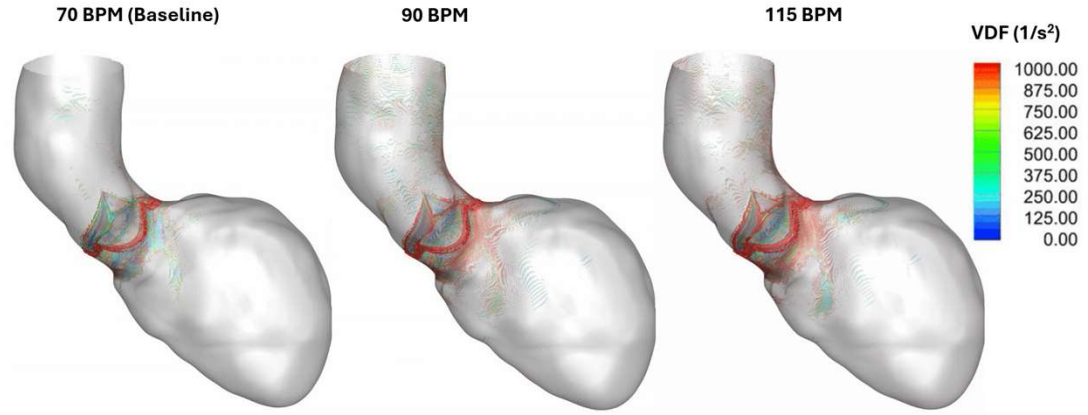
Predict aortic hemodynamics under activity

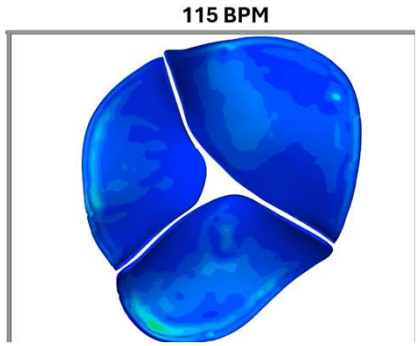


Quantification of valve stresses under activity



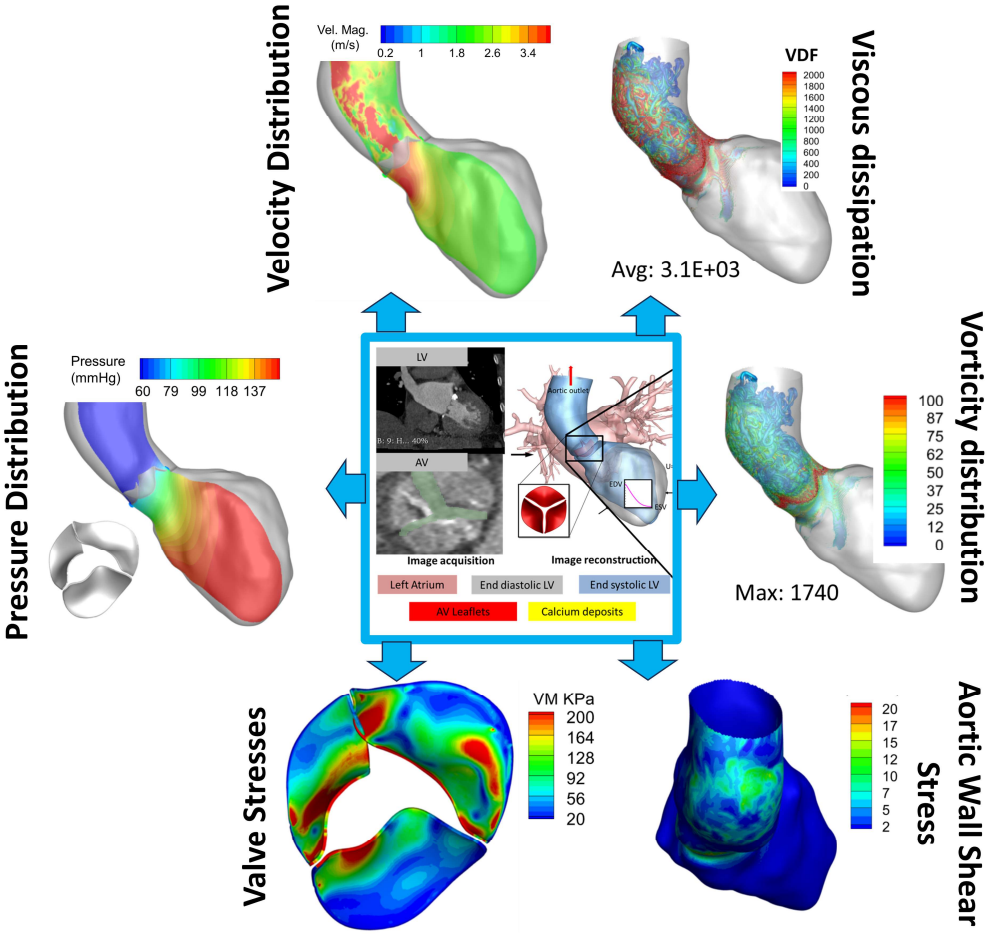
Quantification of dissipative losses under activity

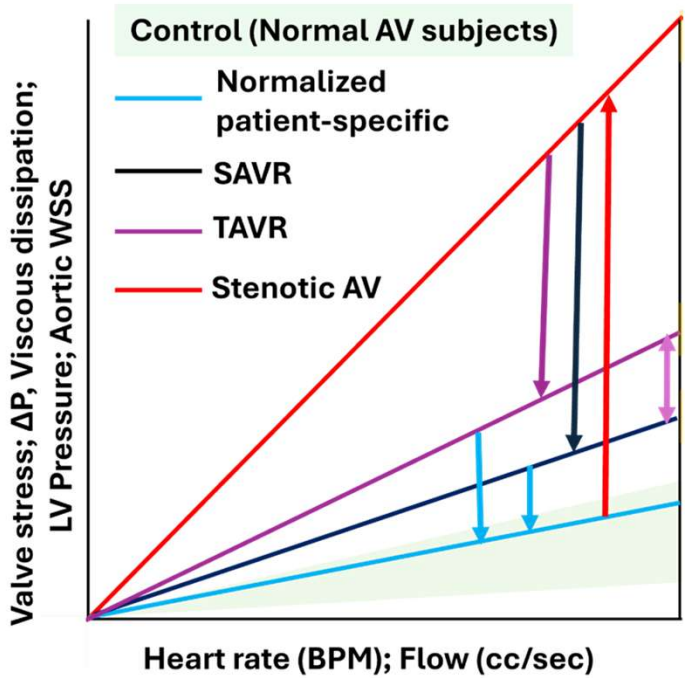




Manuscript Under Review

Biomechanics-based Metrics to compare SAVR and TAVR performance





Quantification of disease severity

Degree of restoration by TAVR

Degree of restoration by SAVR

Conclusion

- **Post-Interventional biomechanics** – By predicting valve deformation, transvalvular pressure gradients, and energy dissipation, FSI-based virtual surgeries provide insights into long-term valve durability, efficiency, and reintervention risks.

- **Patient-Specific Optimization** – FSI-based virtual surgeries enables precise predictions of valve performance, helping to tailor intervention strategies based on individual anatomy.

- **Virtual Stress Testing for Decision Support** – FSI-based virtual stress tests offer a viable approach to predict valve performance under physiological and exercise conditions towards predicting the robustness of the planned intervention.

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Transformational Project Award