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Post Graduate

"Patient specific transcatheter aortic valve replacement therapy pathway with computational fluid structure interaction analysis"

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BACKGROUND

- Total cardiovascular disease (CVD) prevalence risen dramatically from 271 million in 1990 to 523 million in 2019, and CVD fatalities climbed gradually from 12.1 million in 1990 to 18.6 million in 2019 [1].
- According to American Heart Association statistics, annual heart valve procedures in the United States is above 100,000 in 2013, with approximately 50,000 AV replacements [2].
- The ideal replacement valve should be durable, should be resistant to thrombosis, and should have excellent hemodynamics features.
- Transcatheter aortic valve replacement (TAVR) has been introduced about two decades ago as an alternative for minimally invasive implantation of new generation bioprosthetic heart valves.
- Computational modeling can be used during therapy planning for the selection of appropriate replacement valves for TAVR

OBJECTIVE

- In this NPRP funded project, we are establishing a mechanical and FSI analysis path, for a detailed patient-specific hemodynamics analysis for TAVR, considering the most important parameters affecting TAV efficiency.
- This approach will enable to choose of the most suitable TAV type and deployment position for the treatment.

MATERIALS AND METHODS

Input

Patient Specific 3D Model

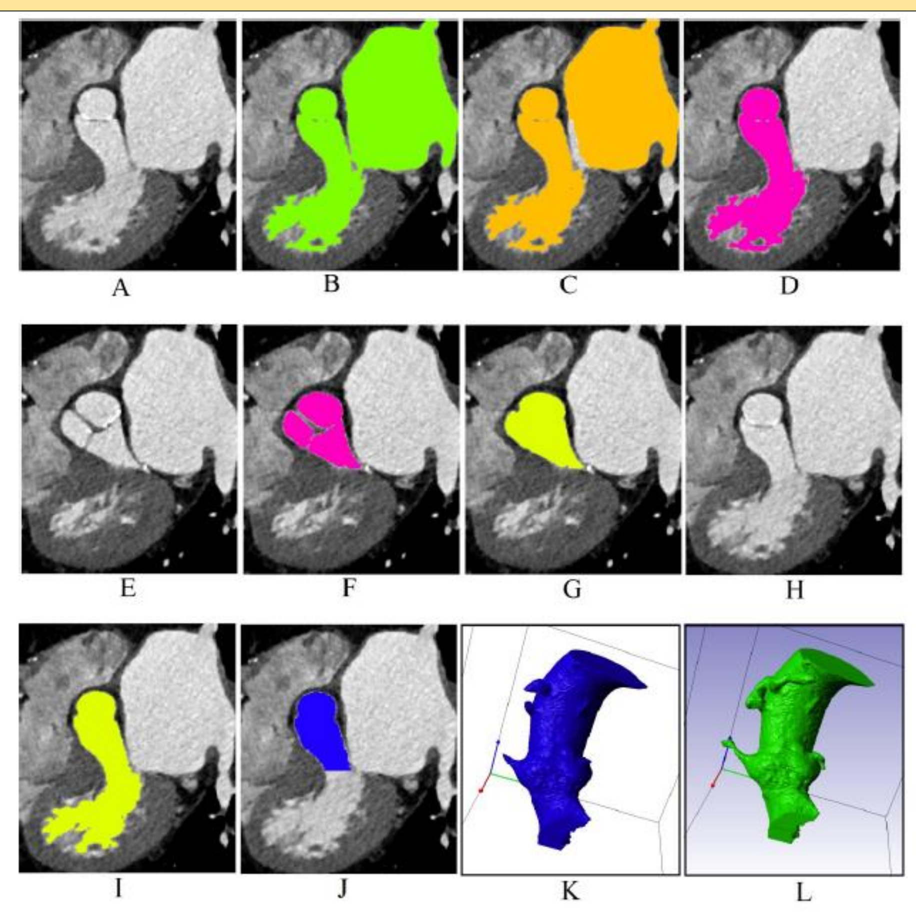


Figure1 : Patient specific aortic root segmentation from medical images [3]

Mathematical Approach FEA

Stent and Balloon Crimping

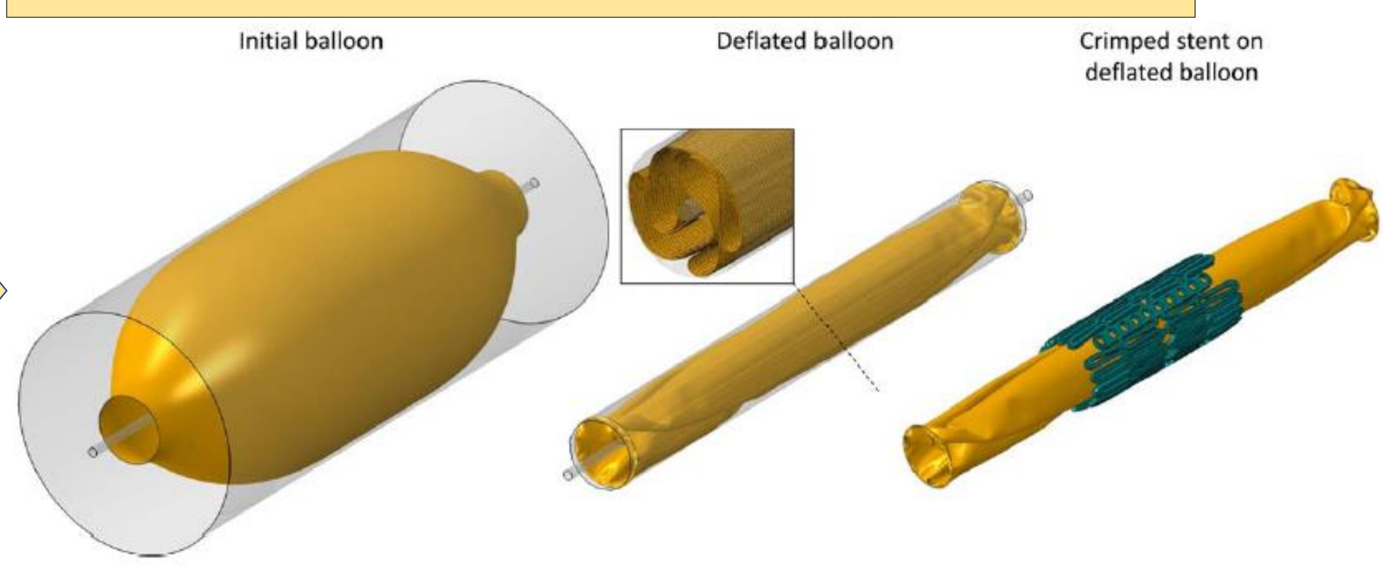


Figure2 : Crimped stent centrally placed on the deflated balloon [4]

TAV Deployment

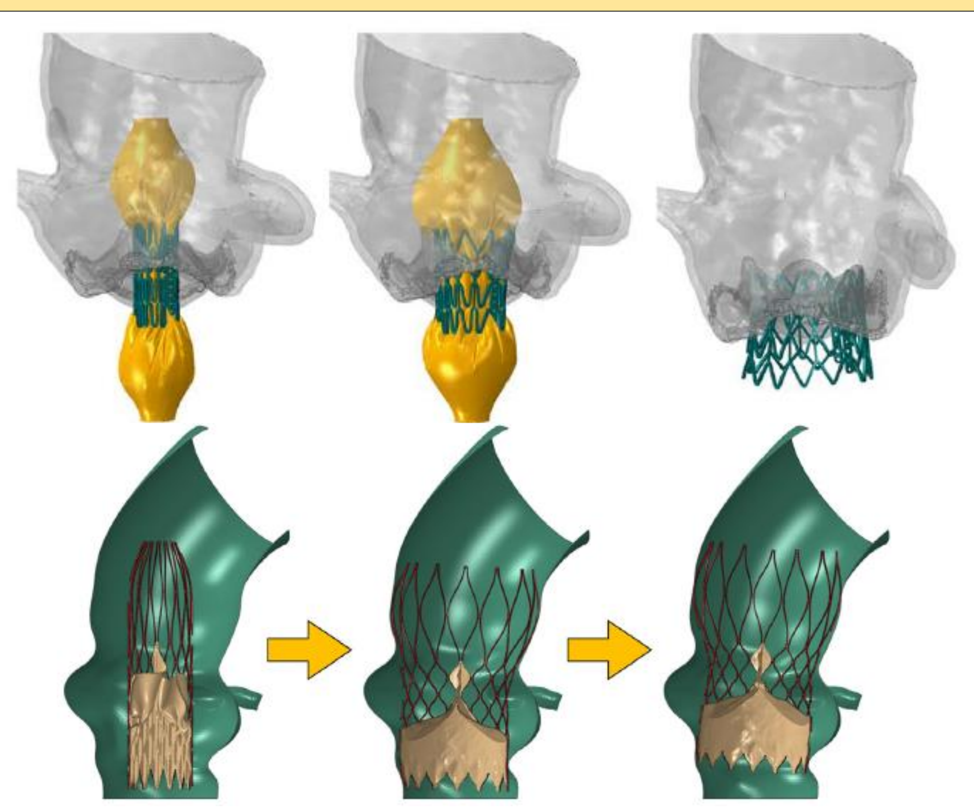
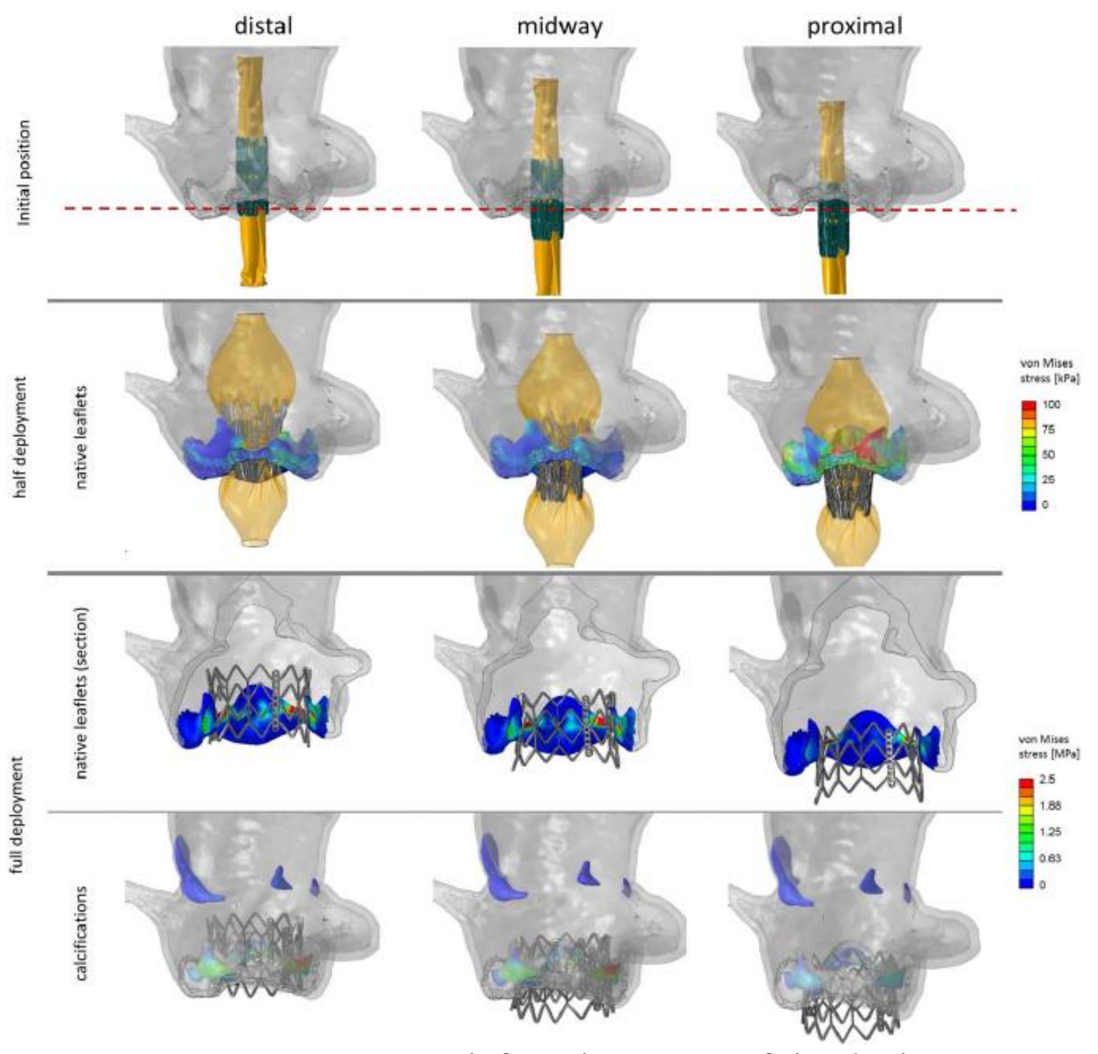


Figure3 : Balloon assistant [4] and self expended TAV deployment [5]

ANALYSIS PATHWAY

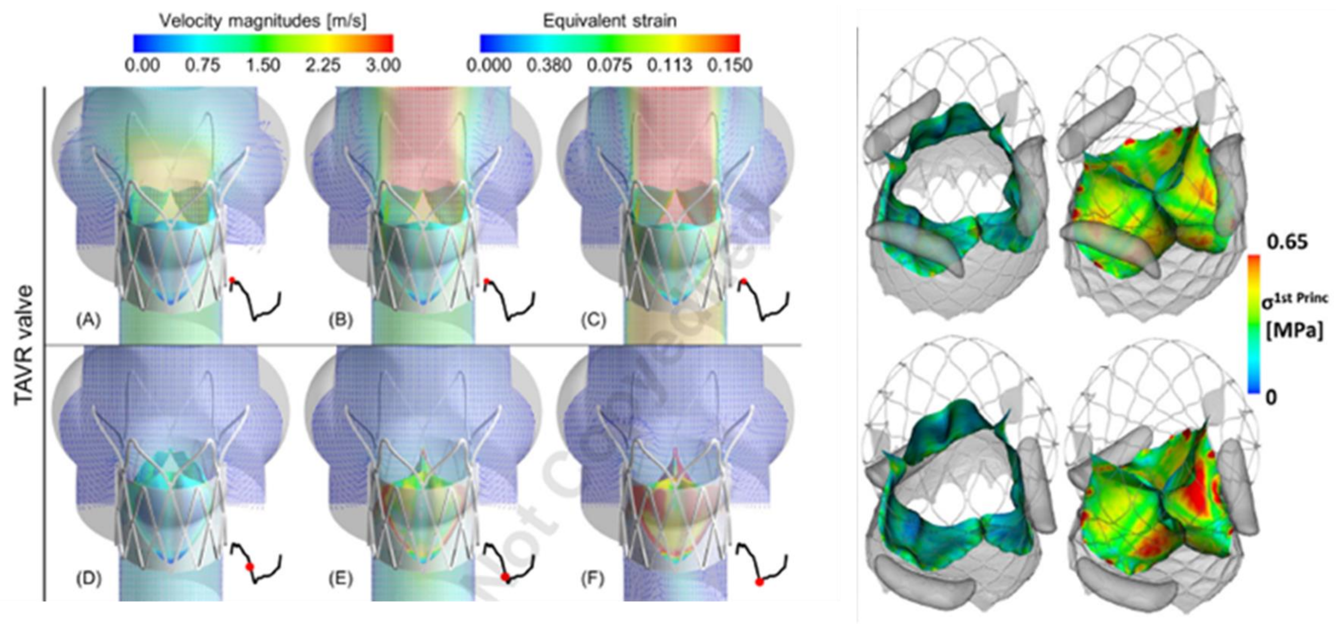
1-Contact Pressure and Area Calculation in Different Deployment Positions



FEA

Figure4 :Contact pressure result from beginning of the deployment to end [4]

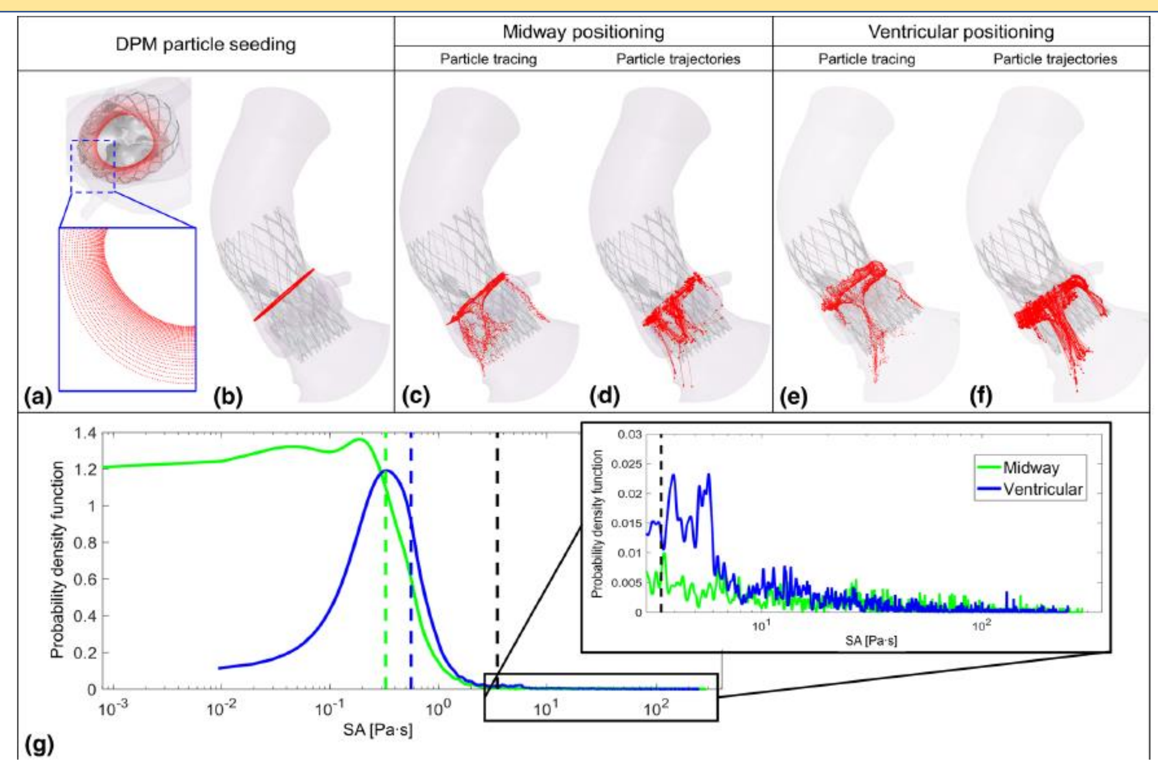
2- Calculating aortic jet velocity and principal stresses



FSI

Figure5 : Calculating jet velocity and principal stresses on the TAV stent and valves [6]

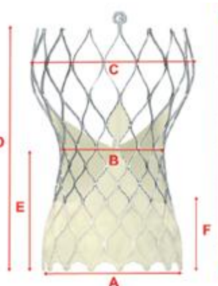
3- Paravalvular leakage analysis



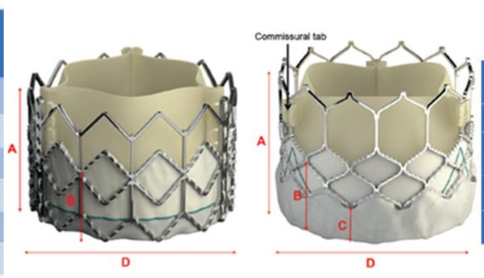
FSI & LAGRANGIAN

Figure6 : Paravalvular leakage analysis with particle method [7]

4- Choosing most suitable TAV



	23mm Evolut R / PRO	26 mm Evolut R / PRO	29mm Evolut R / PRO	34mm Evolut R
A. Inflow Diameter	23 mm	26 mm	29 mm	34 mm
B. Waist Diameter	20 mm	22 mm	23 mm	24 mm
C. Outflow Diameter	34 mm	32 mm	34 mm	38 mm
D. Frame height	45 mm	45 mm	45 mm	46 mm
E. Commissure Height	26 mm	26 mm	26 mm	26 mm
F. Skirt Height	13 mm	13 mm	13 mm	14 mm



	23 mm Sapien XT	26 mm Sapien XT	29 mm Sapien XT	20 mm Sapien 3	23 mm Sapien 3	26 mm Sapien 3	29 mm Sapien 3
A. Frame Height	14 mm	17 mm	19 mm	15.5 mm	18 mm	20 mm	22.5 mm
B. Inner Skirt Height	6.7 mm	8.7mm	11.6 mm	7.9 mm	9.3 mm	10.2 mm	11.6 mm
C. Outer Skirt Height	N/A	N/A	N/A	5.2 mm	6.6 mm	7.0 mm	8.1 mm
D. Valve Diameter	23 mm	26 mm	29 mm	20 mm	23 mm	26 mm	29 mm

EXPECTED RESULTS

With this advanced analysis and simulation path, we expect to accurately estimate clinical TAVR parameters such as contact pressure, contact area, principal stress, etc. before the operation during therapy planning. This approach will help clinicians in optimal valve selection for TAVR patients

REFERENCES

[1] G. A. Roth *et al.*, "Global Burden of Cardiovascular Diseases and Risk Factors, 1990-2019: Update From the GBD 2019 Study," *J. Am. Coll. Cardiol.*, vol. 76, no. 25, pp. 2982–3021, 2020.

[2] B. EJ *et al.*, "Heart Disease and Stroke Statistics-2017 Update: A Report From the American Heart Association," *Circulation*, vol. 135, no. 10, pp. e146–e603, Mar. 2017.

[3] J. Bailey, "Implications for leaflet behaviour in heavily calcified patient-specific aortic roots: simulation of transcatheter aortic valve implantation," 2015.

[4] M. Bianchi *et al.*, "Effect of Balloon-Expandable Transcatheter Aortic Valve Replacement Positioning: A Patient-Specific Numerical Model," *Artif. Organs*, vol. 40, no. 12, pp. E292–E304, 2016.

[5] H. S. Kandail *et al.*, "Impact of annular and supra-annular CoreValve deployment locations on aortic and coronary artery hemodynamics," *J. Mech. Behav. Biomed. Mater.*, vol. 86, no. February, pp. 131–142, 2018.

[6] G. Luraghi, J. F. R. Matas, M. Beretta, N. Chiozzi, L. Iannetti, and F. Migliavacca, "The impact of calcification patterns in transcatheter aortic valve performance: a fluid-structure interaction analysis," *Comput. Methods Biomech. Biomed. Engin.*, vol. 0, no. 0, pp. 1–9, 2020.

[7] R. P. Ghosh, G. Marom, M. Bianchi, K. D'souza, W. Zietak, and D. Bluestein, "Numerical evaluation of transcatheter aortic valve performance during heart beating and its post-deployment fluid–structure interaction analysis," *Biomech. Model. Mechanobiol.*, vol. 19, no. 5, pp. 1725–1740, 2020.