# BIOMECHANICAL ANALYSIS OF AORTIC ROOTS: DIFFERENCES BETWEEN TRICUSPID AND BICUSPID AORTIC VALVE PATIENTS

**P. Mortensen (1), C. Rosnel (1), A. Pouch (2), A. Aggarwal (1)**

*1. University of Glasgow, United Kingdom; 2. University of Pennsylvania, United States of America*

## Introduction

Aortic root connects the left ventricle to the ascending aorta and houses the aortic valve (AV) ensuring one-direction flow of blood during systole. The AV is normally composed of three leaflets, known as tricuspid aortic valve (TAV), but 1-2% of the population is born with only two leaflets, known as bicuspid aortic valve (BAV). The patients with BAV are considered at high risk of developing aneurysms and eventually dissection. The biomechanics of aortic root tissues are hypothesized to play an important role in the disease development. In this study, we use in-vivo echocardiographic images from TAV and BAV patients to analyze the differences in the biomechanics of aortic root tissues.

## Methods

3D transesophageal echocardiographic (TEE) images of the aortic root were retrospectively acquired from 16 patients with the approval of the Institutional Review Board at the University of Pennsylvania. The images were segmented, registered, and converted into a medial model as presented in a previous study [1]. The medial models were remeshed with an quadrilateral elements.

Two methods were used for the biomechanical analysis: 1) patient-specific 3D inverse finite element (FE) modeling, and 2) population-level Bayesian inference based on radius variations. In the first approach, the frame just before AV opens was considered to be the reference, starting frame for the FE simulation, which was performed in FEBio [2]. Pressure waveform was determined using a Wind-Kessel model. Then, the displacement from other time frames was used to fit the biomechanical parameters of the finite element simulation using SciPy's least square fitting algorithm.

In the second approach, radius and longitudinal stretch at the sinotubular junction (STJ) were extracted from the medial models. The root was modeled as a uniform cylinder with a closed-form solution of the governing equations, thus circumventing the need of finite element solver. A Fourier decomposition was performed to reduce the dimensionality and remove the effect of time-shift between images. A Bayesian approach previously developed [3] was used to infer the model parameters, including the reference radius and the stresses in the tissues, by matching the radius in the Fourier domain.

## Results

The two approaches provided distinct advantages. The first, patient-specific approach preserves geometric details, but the effect of diastolic pressure and opening angle could not be accounted form. The second, Bayesian approach allowed us to calculate the population-level differences between TAVs and BAVs, but it discarded part of the information available from the images.

The medial models of all TAVs and BAVs are shown in Fig. 1. The two groups are size matched, but still have some differences in their shapes [1].

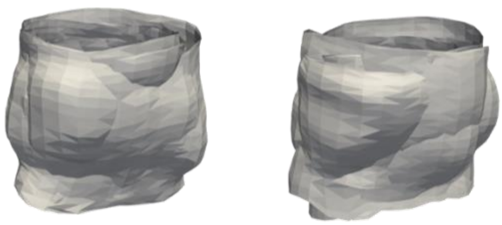

*Figure 1 The medial models of aortic roots for patients with TAV (left, n=7) and BAV (right, n=9)*

The radii at STJ after Fourier interpolation for TAVs and BAVs are shown in Fig. 2. Both approaches provided us with biomechanical stresses for TAVs and BAVs, which showed differences, even before aneurysms develop.

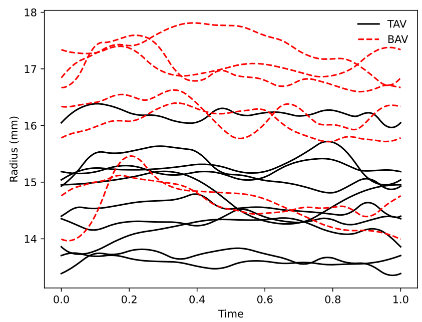


*Figure 2 The interpolated radius at STJ for patients with TAV (black, solid) and BAV (red, dashed)*

## Conclusion

The biomechanical differences we found in this work indicate that the aortic root tissue in BAV patients experience different intramural stresses that might be linked to the higher risk of aneurysm development. Future work will include implementation of growth and remodeling framework to further establish this link.

## References

1. Aggarwal, Ankush, et al. "Strain estimation in aortic roots from 4D echocardiographic images using medial modeling and deformable registration." *medRxiv* (2022): 2022-11.
2. Maas, Steve A., et al. "FEBio: finite elements for biomechanics." (2012): 011005.
3. Aggarwal, Ankush, et al. "A Bayesian constitutive model selection framework for biaxial mechanical testing of planar soft tissues: application to porcine aortic valves." *Journal of the Mechanical Behavior of Biomedical Materials* (2023): 105657.