
# A FLUID-STRUCTURE INTERACTION APPROACH TO DISTINGUISH BETWEEN TRUE AND PSEUDO-SEVERE AORTIC STENOSIS

**Sabine Verstraeten (1), Martijn Hoeijmakers (2), Frans van de Vosse (1), Wouter Huberts (1)**

*1. Eindhoven University of Technology, The Netherlands; 2. ANSYS, The Netherlands;*

## 1. Introduction

Valve replacement therapy is recommended for patients with severe aortic stenosis (AS), i.e., a mean transvalvular pressure drop ($\Delta p$) > 40 mmHg, and an aortic valve area (AVA) < 1 cm$^2$ [1]. However, 50% of the patients [2] with an AVA < 1 cm$^2$, have a $\Delta p$ < 40 mmHg (low gradient AS). In these cases, the low $\Delta p$ might be caused by a low cardiac output that prevents the aortic valve from fully opening. To diagnose stenosis severity in these cases, dobutamine is administered to increase flow. If AVA remains small, but $\Delta p$ exceeds 40 mmHg, it is classified as a true severe AS, and valve replacement is recommended. If the AVA exceeds 1 cm$^2$ and $\Delta p$ remains small, it is a pseudo-severe AS, and valve replacement will not be effective. Unfortunately, for 30% of the low gradient AS patients, flow increases insufficiently upon dobutamine [2], and AS severity remains undetermined. Patient-specific fluid-structure interaction (FSI) simulations of the aortic valve [3] can impose higher flows, independent of the patient's cardiac function. In this study we aim to leverage FSI simulations to distinguish between true and pseudo-severe AS. Two cases were simulated: (1) severe AS and (2) low-gradient AS, for which severity is yet to be determined.

## 2. Materials and Methods

FSI simulations were performed in LS-DYNA, using a generic aortic valve geometry modified from *dynaexamples.com*. Blood was modelled as an incompressible Newtonian fluid. A flat, sinusoidal velocity profile (with negative values set to 0) with a cycle time of 0.86 s was prescribed at the inflow boundary, with a maximum velocity of 0.25, 0.5, 1.0, 1.5 and 2.0 m/s. At the outflow boundary a pressure of 0 Pa was prescribed. The leaflets were modelled as a linear elastic material, with a shell thickness of 1 mm, and a Young's modulus of 10 MPa and 1 MPa for case 1 and 2, respectively. Forces and displacements were exchanged between fluid and mechanical solver through strong coupling.

## 3. Results

For both cases, the AVA at the lowest inflow velocity was below 1 cm$^2$. Pressure drops for case 1 and 2 were 152 mmHg and 34 mmHg, respectively. Figure 1 shows that for case 1, AVA remained small, even for the highest flows, which indeed corresponds to a severe AS. For case 2, AVA already exceeded the limit of 1 cm$^2$ significantly at 125 ml/s, indicating that it is a pseudo-severe AS.

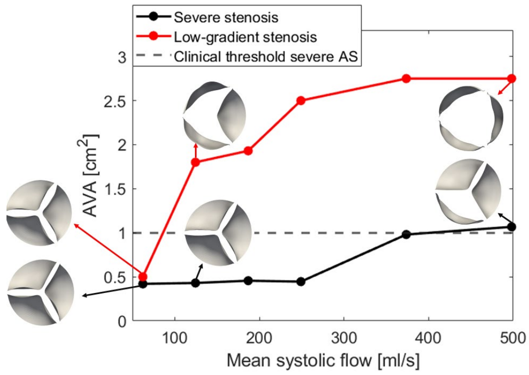


**Figure 1**: AVA as a function of mean systolic flow, and corresponding leaflet configurations.

## 4. Discussion and Conclusions

The presented FSI approach was able to simulate two complete cardiac cycles, including both valve opening and closing. We showed that we were able to distinguish between true and pseudo-severe AS, for the low-gradient case. This modelling framework is currently being expanded to patient-specific geometries and boundary conditions. The main challenge will be to establish a method to determine patient-specific material properties.

## 5. References

1. Nishimura et al., Circ., 129.23: e521-e643 (2014)
2. Clavel et al., Eur. Heart J. 37.34 2645-2657 (2016)
3. Govindarajan et al., Ann. Biomed. Eng.: 1-11 (2023)

**Acknowledgements:**

We acknowledge the European Union's Horizon 2020 research and innovation programme (grant agreement No 101017578) for their financial support.