PARTICLE TRACING IN AORTIC ROOT MODELS INVESTIGATING SINUS WASHOUT IN TRANSCATHETER VALVE THROMBOSIS PATIENTS

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Objective

Transcatheter heart valve thrombosis (THVT) is associated with reduced leaflet mobility, valve degeneration and possibly higher risk of stroke [1]. Data from the Bern Transcatheter Aortic Valve Implantation (TAVI) registry indicates that patients diagnosed with THVT might have a larger ascending aorta (AAo) compared to respective TAVI patients without THVT.
This computational study aims to compare blood flow patterns in aortic root geometries with larger AAo as observed in THVT patients to those found in unaffected TAVI patients.

Computational Method

Two computational models of a parameterized aortic root with a biological tissue valve are created:
(a) a model representing TAVI patients without THVT (control) and (b) a model with larger AAo as observed in THVT patients (THVT).
The interaction of the motion of aortic wall and valve with the surrounding blood flow is implemented in a high-fidelity fluid-structure interaction solver. The coupling of a high-order Navier-Stokes solver [2] and the structural solver is achieved by an Immersed Boundary approach based on variational transfer [3]. Average systolic transvalvular pressure gradients are imposed according to patient data of Franzone et al. [4]. The resulting flow fields are analyzed and turbulent dissipation is quantified. To assess the washout efficiency of the sinus portions mass-less Lagrangian particles are seeded immediately upstream of the valve and traced over time periods of 0.1s. The traces are categorized into groups of particles that are advected into the ascending aorta, particles that contribute to the sinus washout, and particles that stagnate in the sinus portions.

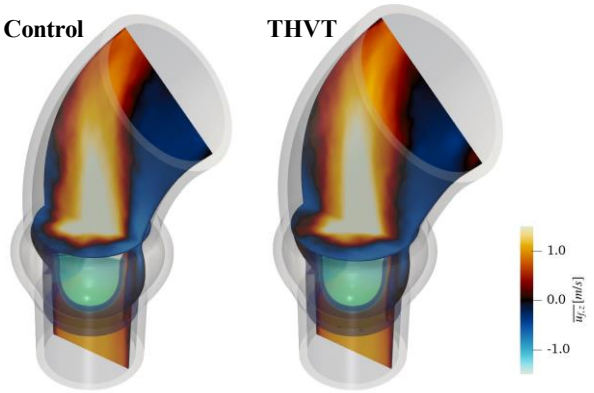

Figure 1: Mean streamwise flow velocities $\overline{u_{f,z}}$ for control and THVT aortic model.

Results

Although peak jet velocities during systole are comparable in both models, systolic backflow velocities towards the sinus portions are lower in the THVT model. Also, lower mean flow velocities and a lower turbulent dissipation rate can be observed in the sinus portions. However, the systolic turbulent dissipation rate in the AAo is higher in the THVT model compared to the control group.
Lagrangian particle tracing reveals that most of the injected particles are advected directly through the ascending aorta (84% for control vs. 88% for THVT). However, more particles enter, but also leave the sinus and therefore contribute to the washout for the control model (+78%) compared to the THVT model.

Conclusions

A higher systolic turbulent dissipation rate in the larger ascending aorta of THVT patients might promote blood platelet activation. Lower systolic turbulent dissipation rate and lower velocities within the sinus indicate a lower washout rate. This is supported by the higher amount of washed-out particles for the control compared to the THVT model, suggesting a much lower washout efficiency of the sinus in THVT patients. The combination of the observed flow patterns could lead to thrombus formation and provide a possible explanation for the link between aortic root morphology and THVT.

References

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