Correlation between wall shear stress and wall rupture properties in ascending thoracic aortic aneurysms

Stéphane Avril, Mines Saint-Étienne, France

Aim-Ascending thoracic aorta aneurysm (ATAA) is the 19th common cause of human deaths. Despite important recent progress to better understand the pathogenesis and the development of the disease, the role played by deranged hemodynamics on the ATAAs risk of rupture is still partially unknown. The aim of this study is to obtain crucial indications about this role by combining in vivo, in vitro and in silico analyses (Figure 1).

Methods-Computational fluid dynamics analyses were performed on 10 patients using patient-specific geometries and boundary conditions derived from 4D MRI. Blood flow time-averaged wall shear stress (TAWSS), helicity and eccentricity descriptors were assessed. A bulge inflation test was carried out in vitro on the 10 ATAAs after surgical repair. The biomechanics and rupture properties of these samples were derived: burst pressure, physiological tangent modulus (E_{physio}), Cauchy stress at the rupture stage (σ_{rup}), rupture stretch (λ_{rup}) and rupture stretch criteria ($\gamma_{stretch}$). Spearman's rank-order correlation was performed to determine association between all variables.

Results-The results showed a statistically significant (p<0.01) negative correlation between E_{physio} and the TAWSS (r=-0.77 and p=0.009). A statistically significant positive correlation was found between σ_{rup} and the TAWSS (r=0.879 and p=0.001) and between λ_{rup} and the TAWSS (r=0.867 and p=0.001).

Conclusions-In conclusion, this study demonstrates that large TAWSS have a protective effect in ATAA as they are related to larger rupture properties and smaller stiffness. Further investigations will be extended to a bigger cohort of patients.

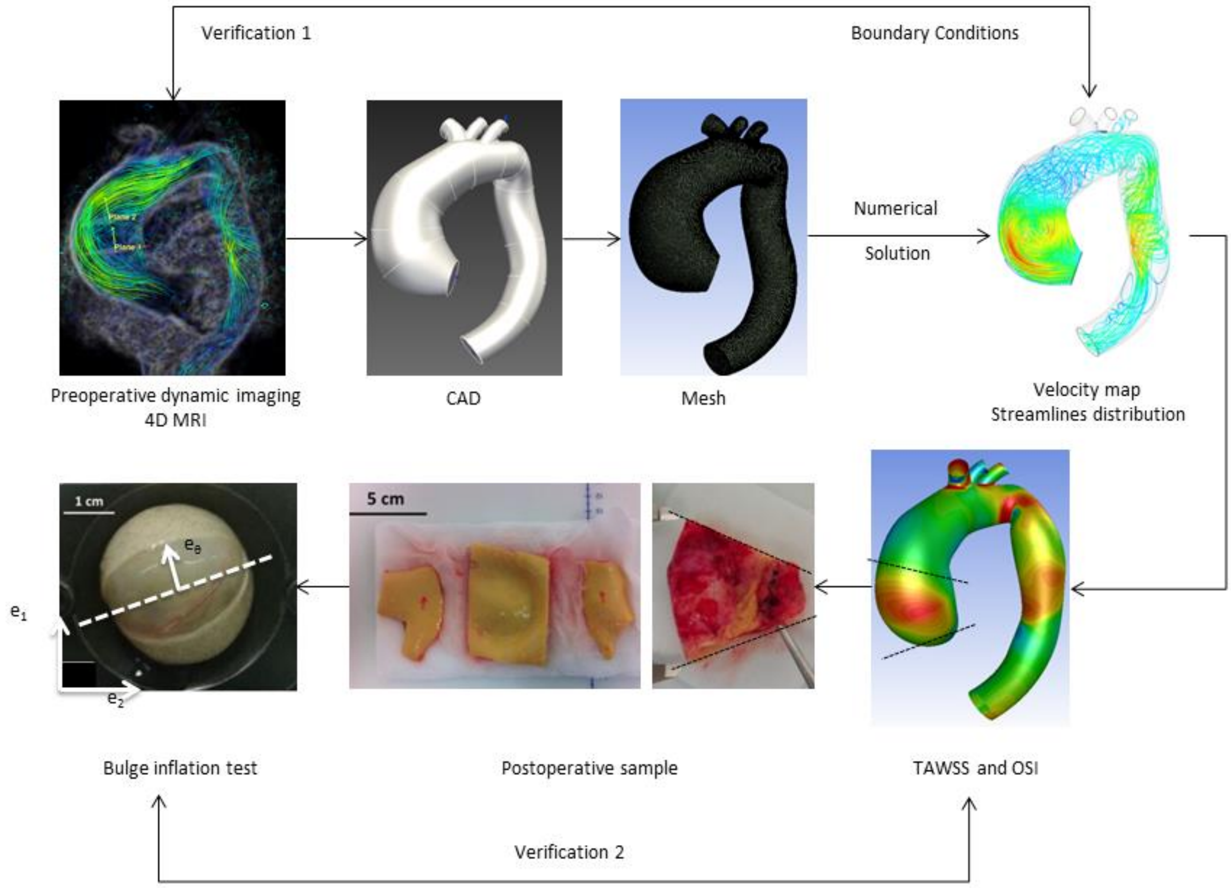

Figure 1. The figure shows a workflow overview of the analysis presented in this work. Firstly, the 3D geometry was constructed using patient-specific images; secondly, the CFD model was built and solved using patient-specific boundary conditions from 4D MRI acquisition; thirdly, the CFD model was verified using 4D MRI data. Finally, biomechanics and rupture properties of these samples were assessed.