Effect Of The Rotational Position Of Aortic Root On Regional Hemodynamics And Biomechanical Differences

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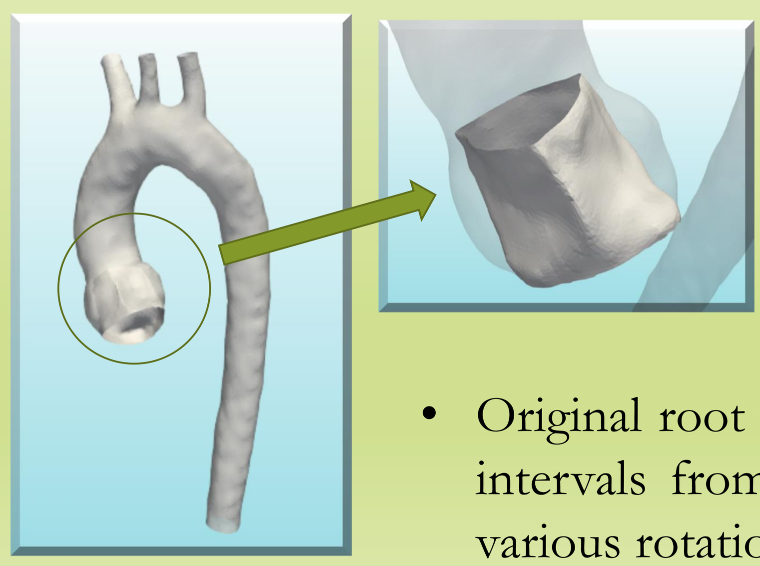
INTRODUCTION :

Sinus of Valsalva generates vortical structures that help in opening/closing of the valve. These flow structures interact with *Dean Vortices[1]*, formed because of curvature in ascending aorta and subject the aorta wall to discrete bouts of shear stress. Computational Fluid Dynamics (CFD) , an important tool in studying the influence of aorta mechanics on hemodynamics and vice versa [2,3], has been used to investigate this flow interaction by changing the orientation of valve leaflets with respect to the local curvature of ascending aorta.

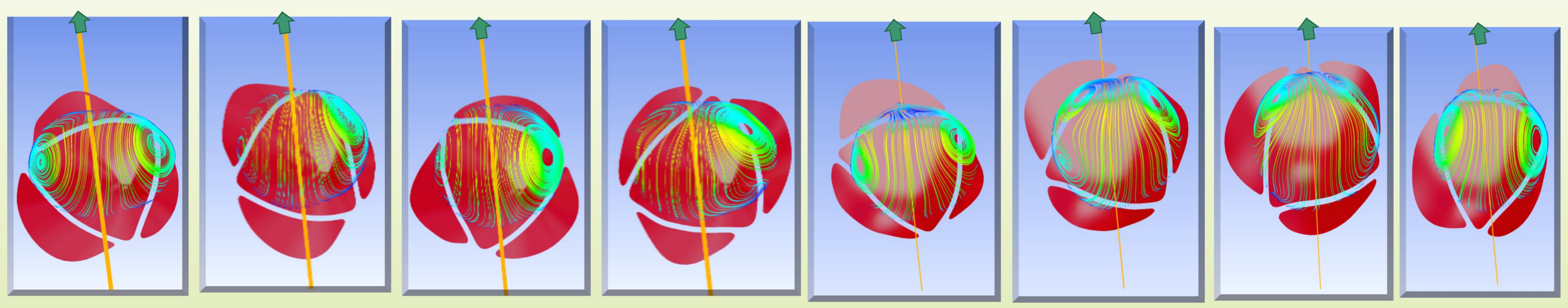
METHODS :



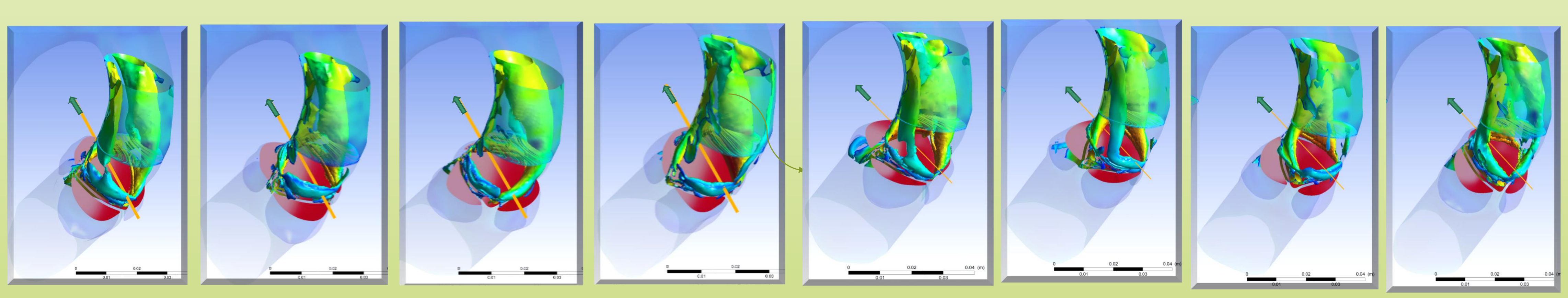
- Thoracic Aorta was modeled from MRI scan. Fully open valve was constructed based on the lines of commissure.
- Patient specific peak flow rate was obtained from Phase Contrast MRI.
- Steady flow simulations were run with k-ε turbulence models.
- Only ascending section of aorta was focused on for this study since the flow further downstream depends on more variables.
- Original root with valve is rotated about the axis of flow input direction in equal intervals from 0 to 360 degrees and resulting flow structures are compared in various rotations.

SIMULATION RESULTS :

Plane of local curvature at the start of ascending aorta with arrow pointing to inside of curvature

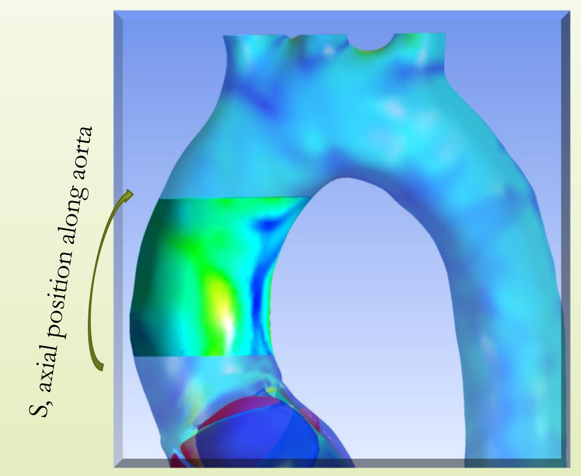


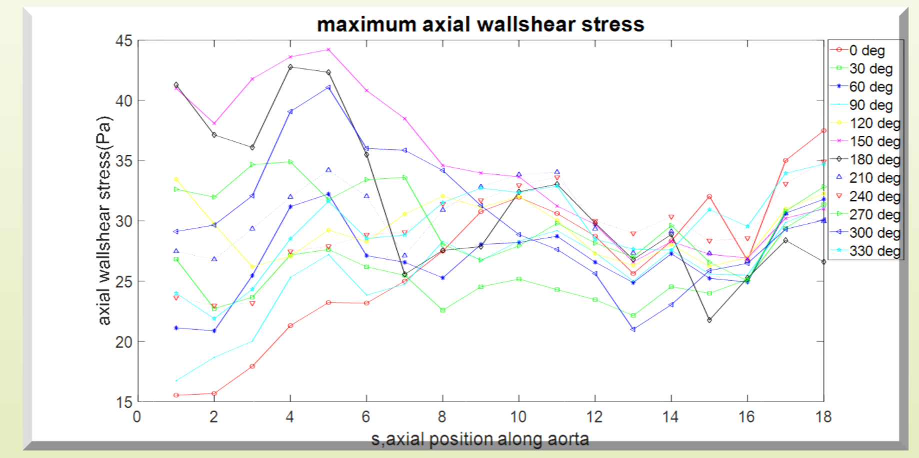
0 deg | 30 deg | 90 deg | 150 deg | 240 deg | 270 deg | 300 deg | 330 deg

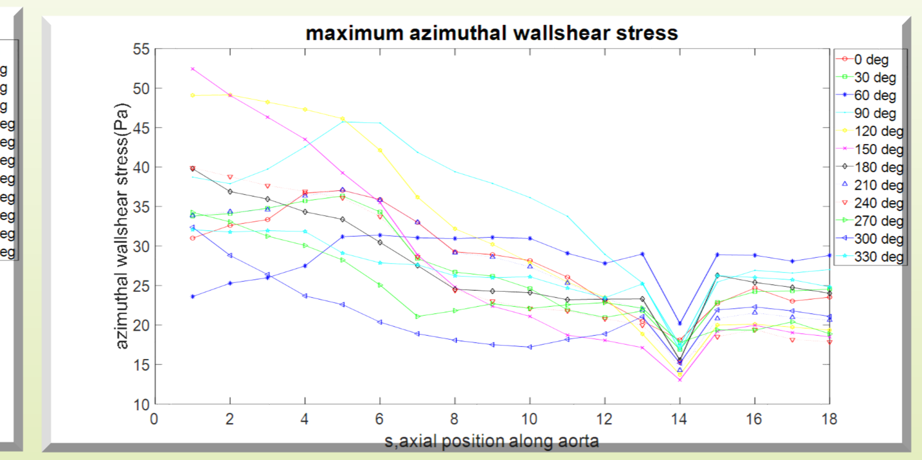


- Dean vortices (shown in plane at the start of ascending section) are predictably found to be in same position irrespective of the orientation of root since the curvature of aorta is still the same.
- Although positions of the vortices are same, their strength depends very much on the orientation of leaflets and the size of corresponding aortic sinus.
- Flow structures (shown using lambda 2 parameter) demonstrate the origin of vortices at free edges of leaflets.

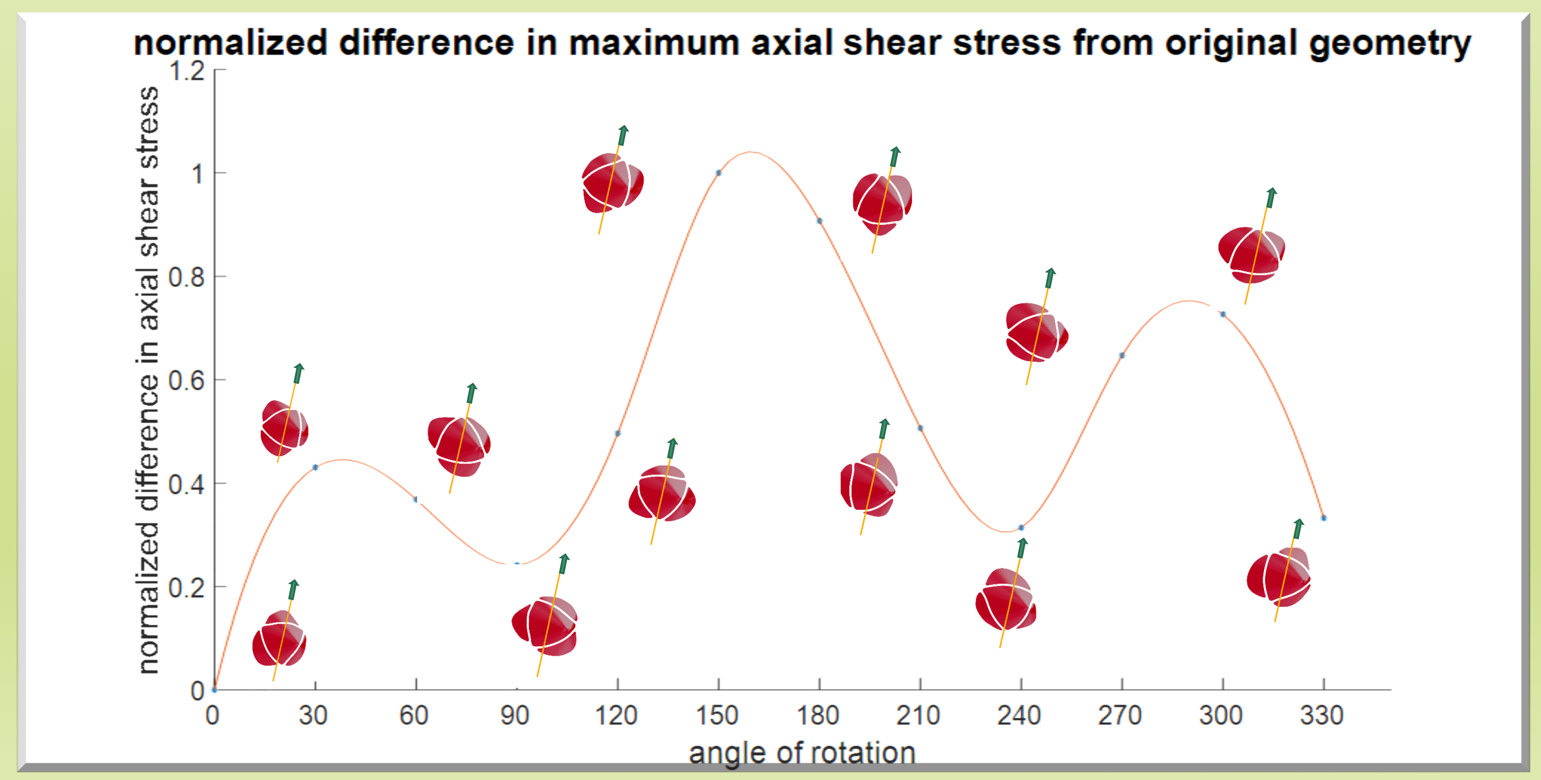
ANALYSIS :

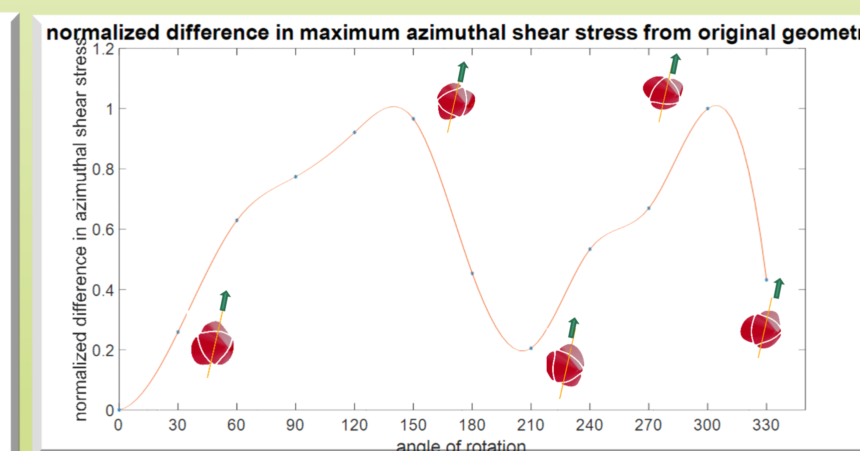






- Shear stress trend in both components seems to reverse along the aorta. This could be because of the transport of shear inducing flow structures by vortices from inside the flow to near wall and vice versa for various orientations.





- Axial component of stress reflects the root symmetry for every 120 degrees change as expected.
- All the respective geometries on peaks and troughs have strikingly similar geometries.
- Azimuthal component seems to rely more on sinus sizes than orientation.

CONCLUSION :

- Axial wall shear stress tends to be higher if sinus is on outside of curvature when compared to the geometries with sinus on inside of curvature. This trend reverses along the aorta although magnitudes become less severe.
- Size of aortic sinus also plays a significant role in regional stress distribution in ascending aorta.

FUTURE STUDIES :

- Confirmation of this observation in different patient data.
- Flow studies with valves of different opening sizes followed by fluid-structure interaction simulations.

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