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Computational Flow Dynamics Modeling Across A Severe Fixed Aortic Valve Stenosis And Its Correlation With Doppler Velocities

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Background: The aim is to generates a fixed severe calcific aortic stenosis geometry from a patient's Computed Tomography (CT) anatomical data and simulate flow across this valve using a simplified 2D Computation Fluid Dynamics (CFD) model and compare the simulation to actual Doppler data from the patient. Aortic valve consists of three leaflets that are passive structures that open and close based on the pressure gradients between the left ventricle and the aorta. Calcium deposits in the valve cusps produce lack of mobility that can progress to a rigid fixed obstruction. In this setting, jet velocities can range from 4 to 7 m/s depending on the severity of the obstruction.

Methods: The aortic valve geometry of a specific patient with severe fixed aortic stenosis was obtained from CT scan data. Using Solid Works, a 3D geometrical model was created and exported to create a mesh with Gambit software. This model was further simplified to a 2D model using the cross-sectional view of the 3D model. After sensitivity analysis, a simplified mesh of 13,406 nodes and 13,105 quadrilateral cells was made to simulate the flow velocities. This mesh has a higher node density towards the area of interest, which are the leaflet orifice and outflow tract. The boundary conditions were set in the inflow and outflow tract of the aortic valve. The velocities in the Left Ventricular Outflow Tract and across the aortic valve were obtained using Doppler. These velocities were compared with the ones obtained using CFD. To simulate the systolic cardiac cycle, a user define function in 2D laminar simulation of a Newtonian fluid was implemented.

Results: The computational flow dynamic model simulated the peak velocity across the valve accurately compared to the one obtain with Doppler (569 cm/s vs 600 cm/s, 8% error). The Wall shear stress obtained in the leaflets ranged from 30-70 Pa, which is consistent with the shear stress reported in the literature.

Conclusions: A simplified 2D CFD model can accurately predict the velocities across a fixed stenosis calcific aortic valve. This information could be helpful in further assessment of the aortic valve area based on time velocity integral of the outflow and inflow tract of the valve.

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IFR PLUS INTRACORONARY NITROGLYCERINE: A NEW PHYSIOLOGICAL INDEX OF LESION SEVERITY

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Background: The instantaneous wave-free ratio (iFR) is a vasodilator-free pressure-only measure of the hemodynamic severity of coronary stenoses that is comparable to the classical fractional flow reserve (FFR) in diagnostic categorization. The use of iFR might thus replace FFR and avoid potential complications arising from the use of intravenous adenosine. However, whether iFR plus intracoronary nitroglycerine (icNTG) may further improve the diagnostic accuracy of iFR remains to be determined.

Methods: Fifty-five moderate lesions from 44 consecutive patients were evaluated. We compared the diagnostic value of iFR vs iFR plus icNTG, using FFR with intravenous adenosine as the gold standard, to determine cutoff values that would make unnecessary the use of FFR with intravenous adenosine.

Results: Mean age was 66±11 years (77% male). Most patients were studied for an acute coronary syndrome. On quantitative coronary angiography mean stenosis severity was 51±9% whereas mean FFR with intravenous adenosine was 0.80±0.1 and iFR was 0.87±0.08. The diagnostic value of iFR plus icNTG was reduced to 0.77±0.12 ($p< 0.01$ as compared with iFR). Using iFR plus icNTG a cutoff value of 0.81 was associated with a 100% sensitivity for detecting a significant FFR (< 0.8) with a negative predictive value of 100%.

Conclusions: Our findings suggest that iFR plus icNTG using a cutoff value of 0.81 may be used to replaced FFR with intravenous adenosine with adequate accuracy. Nevertheless, further studies are required to confirm the diagnostic accuracy of this new physiological index in the clinical setting.