Aortic coarctation pressure gradient prediction using a computational-fluid-dynamic model: Validation against invasive pressure catheterization at rest and pharmacological stress

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Introduction: Even after successful early repair of Aortic Coarctation(AoCo), life expectancy is still markedly reduced due to long term complications (hypertension) and often invasive diagnostic catheter investigations may be required to evaluate the pressure gradient(PG) across the aorta at rest, or unmask such gradients under pharmacological stress to mimic physical exercise. The objective of this research is to know if a MRI based computational fluid dynamics(CFD) model protocol can accurately predict the pressure gradient in patients with AoCo.

Methods: The study population included 7 cases with aortic coarctation (mean±standard deviation; age 19.4±4.6 years, weight 71.9±17.1kg), who had a previous combined MRI(CE-MRA and 2D CINE-PC) and cardiac catheterization study performed in rest and isoprenaline stress conditions. The 3D CE-MRA data was used to create geometric solid models of the aorta which were then discretized using a tetrahedral mesh generation program(MeshSim,Simmetrix,Clifton Park,NY). The 2D PC-MRI data were used to determine flow waveforms and distribution and to estimate the stiffness of the Aorta. The numerical method solved the Navier-Stokes equations for the flow of an incompressible Newtonian fluid within a deformable domain using a stabilized finite element formulation. Simulations were performed for rest and stress conditions. We compared the PG mean (PG mean-mean) and peak to peak (PG peak-peak) value of the pressure gradient obtained between Catheter and CFD using Bland-Altman and Wilconxon Test.

Results: We have an average of PG mean-mean 2.85±2.47mmHg for the catheterization and 2.76±1.64mmHg for the simulation. For the PG peak-peak, we have an average between all cases of 10.36±6.54mmHg for the catheterization and 9.77±6.39mmHg for the simulation. In stress conditions we obtained an average of PG mean-mean of 12.59±8.61mmHg for the catheterization and 11.25±7.60mmHg for the simulation. The average PG peak-peak was 52.71±22.11mmHg for the catheterization and 37.38±21.64mmHg for the simulation. There were no significant differences between the catheterization and CFD except when comparing the PG peak-peak at stress.

Conclusions: The pressure gradients obtained at rest conditions were in good agreement with the ones obtained from catheterization demonstrating that we can use a systematic method to predict non- invasively pressure gradients using CFD simulation based on cardiovascular MRI.