PULSATILE FLOW IN A SIMPLIFIED AORTA WITH COEXISTING MODEL OF AORTIC STENOSIS AND COARCTATION OF THE AORTA

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INTRODUCTION

The Coarctation of the aorta (COA) is a congenital heart disease defined as an obstruction of the aorta distal to the left subclavian artery. It is mainly associated with bicuspid and tricuspid aortic stenosis. COA is encountered in 0.1% of newborns. In severe cases, COA can result in serious complications such hypertension, left ventricular failure and aortic dissection. As a consequence, 60% of adults over 40 years with uncorrected COA have symptoms of heart failure and ¾ die by the age of 50, and 90% by the age of 60 [1]. The objective of this study is to investigate numerically the flow in a simplified model of the aorta (curved pipe) with coexisting coarctation of the aorta and aortic stenosis. Several severities of coarctations and aortic stenosis were investigated and their impact on secondary flows, wall shear stress and pressure drop in the model of the aorta was analyzed.

METHODS

This study was performed using FLUENT 6.3. In the absence of obstructions (case 0-0), the blood flow is usually laminar and does not experience transition to turbulence, so the solution was obtained by simulating a laminar flow inside the domain.

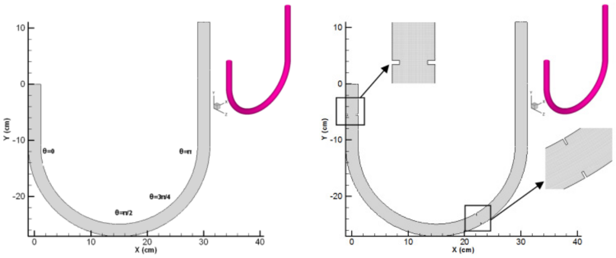

Figure 1: Schematic diagram of the curved tube, (a) with no obstructions, (b) with both stenosis and coarctation.

The obstruction resulting from a stenosis and/or coarctation can lead to disturbed flow regions in the aorta. Ghalichi et al. [2] presented numerical results for transitional and turbulent flow through moderate and several arterial stenoses by applying k-ω turbulence model and concluded that it is suitable for blood flow studies where both laminar/transitional and turbulent flow regimes coexist. Hence, in this study the nine simulated cases with both stenosis and coarctation have been investigated using k-ω turbulence model. Note through this paper, the first index in all figures is effective orifice area of the stenosis and the second one is the coarctation severity (in percentage).

RESULTS AND DISCUSSION

The unsteady simulations were performed with a systolic duration of 300 ms. The results (Figures 2-5) indicate that the presence of obstructions has significantly effects on the hemodynamics of the aorta. secondary flows became stronger leading to a transition from bean-shaped vortices (confined in the regions close to the lateral walls) to mushroom-like vortices (occupying almost the whole section) as a result of increasing valvular stenosis severity. The more skewed axial velocity cause more adverse pressure and more reverse flow which demonstrates the existence of flow separation in the post-stenosis regions.The high pressure loss at the neck of obstructions indicates that they augment the flow resistance and can lead to collapse of the wall. This study also reveals the regions with negative WSS and high OSI which are indicators of atherosclerosis.

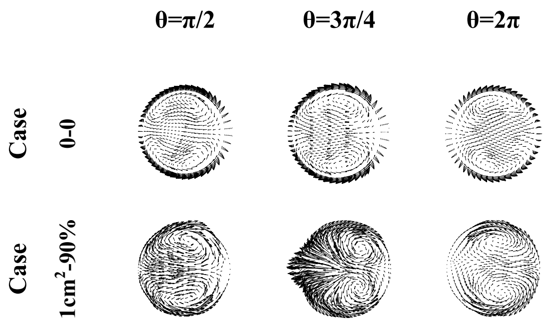

Figure 2: Secondary flow comparisons.

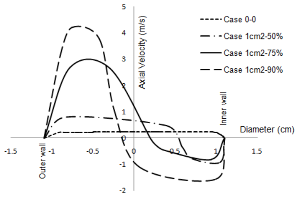

Figure 3: Axial velocity profiles at θ=3π/4 cross section, t=0.08s.

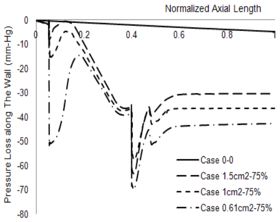

Figure 4: Pressure drop along the central line of the curved tube.

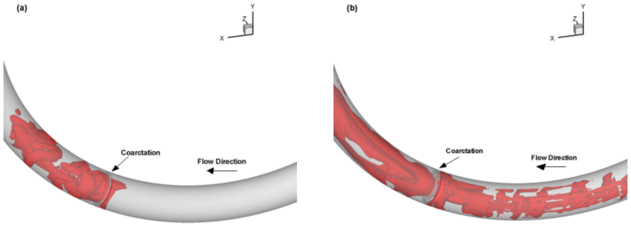

Figure 5: Isosurfaces for Q criterion (Q= 100 m s-1) at t=0.24 s, (a) at 50% coarctation, (b) at 75% coarctation.

REFERENCES

1. Brickner M E, et al., the New England Journal of Medicine.342 (4): 256-63, 2000.
2. Ghalichi F, et al., Biorheology. 35: 281-294, 1998.