International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 04, 2020
ISSN: 1475-7192

Numerical Analysis of Aneurysm in Artery

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Abstract--- *In this article, the numerical solution of blood vessels affected by aneurysm with dilation 25% is analyzed. Hemodynamic factors such as pressure and velocity are computed using Finite Volume Method. High pressure and low velocity is observed in the region of aneurysm. This is a sign to the disruption of blood flow. To understand the relationship between hemodynamic parameters and risk of rupture computational methods plays a vital role.*

Keywords--- *Aneurysm, Hemodynamic, Finite Volume Method (FVM), Velocity, Pressure.*

I. INTRODUCTION

The investigation of physical forces in blood circulation is Hemodynamics. It refers to physical factors governing the flow of blood in circulatory system. Aneurysm is a dome-like dilation is seen on the walls of a blood vessel or a sac formed by the localized dilatation of the wall of an artery or a vein, or the heart.

Natural aneurysm may burst under tenacious inner tension, causing casualty or serious incapacity. Indeed, even an unruptured aneurysm can cause harm by between rupting the progression of blood or by impinging on the mass of the vessel, sometimes disintegrating close by veins, organs, or bone. Aneurysms are seen most oftentimes in huge supply routes like the iliac, femoral, popliteal, carotid or renal courses. Hemodynamic parameters are viewed as answerable for starting development and break of aneurysms. In blood vessel dividers, whenever expanded blood stream happens, it brings about augmentation of vessel width and decrease of shear forces. To comprehend aneurysm conduct, the stream elements are contemplated in huge number test models. Different aneurysms can develop from a proportionate area of a conduit, and in this manner the connection between these aneurysms raises the threat of crack.

Results have been practiced by a few authors in the most recent decade for patients with different aneurysm geometries [7, 8, 9]. The effects of hemodynamic forces on the growth, initiation and rupture of cerebral aneurysms have focused and analyzed [10]. Blood flow in reasonably expanded unbending veins has been numerically examined by Wille [3] to follow stream lines of the flow. The path lines of the stream particles were investigated by Perktold [1]. In the examination made by Rathish Kumar & Naidu [2], single aneurysm has been dissected for various expansions. Computational Fluid Dynamics modeling in basilar aneurysms were examined by Vali, Alireza, et al.[11] and CFD analysis of cerebral aneurysms by Kimura, Hidehito, et al[13]. Li, Miao, et al. discussed on the ruptured intracranial aneurysms [12]. Girija et al. discussed problems on multiple and aortic aneurysm [13, 14]. Kirubhashankar et al. discussed effects of Magneto Hydrodynamic Casson Liquid between conducting plates and

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DOI: 10.37200/IJPR/V24I4/PR201597
Received: 17 Jan 2020 | Revised: 19 Feb 2020 | Accepted: 28 Feb 2020

MHD Flow between Parallel Plates [16, 17].

Blood vessel illnesses because of hemodynamic components are not completely comprehended [1],[2]. Knowledge of shear stress, flow partition and pressure, can give a superior comprehension of the connection between the fluid dynamics in pulsatile blood stream and blood vessel infections.

In this article pulsatile stream of a thick liquid in an enlarged vessel is considered. Limitations on the level of the widening are overlooked. Since the wall of the blood vessel is flexible, neglect the wall dispensability. In arteries change in diameter is about 10% [4], so error in fixed diameter is small.

Formulation of the Problem

- The geometry of the dilated wall with single aneurysm is given by

$$y(x)=\begin{cases} a\left(l+\dfrac{\delta}{2a}\left(l+\cos\left(\dfrac{\pi x}{x_0}\right)\right)\right), & |x|\le x_0 \\ a & |x|\ge x_0 \end{cases} \tag{1}$$

Where $\delta = a - y(x_0)$ (2)

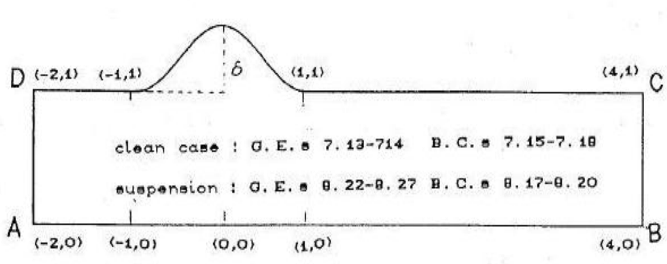

Fig. 1: Geometry of Dilated Vessel with Single Aneurysm

ABCD - Rigid dilated vessel,

l - the length of the vessel,

δ - the measure of the degree of dilation of the vessel,

$2x_0$ - the axial length of the dilation,

$y(x_0)$ - the minimum vertical height of the vessel

a - the maximum vertical height of the vessel

Boundary Conditions are

U = 0, V = 0, on the dilated vessel CD

$U_x = 0$, v = 0 on the central axis AB

U = u(t)=0.2,0.6m/s, v = 0 on the inflow segment AD

$U_x = 0$, $U_Y = 0$ on the outflow segment BC

U=u(t)represents a time-dependent inflow velocity profile

ρ = 1060 [kg/m3] and η = 0.003 [kg/ms] (Poiseuille)

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Governing Equations

Equations of momentum and mass conservation for incompressible fluid can be written as:

$$\nabla . \bar{v} = 0$$

$$\rho\left(\frac{\partial \bar{v}}{\partial t} + \bar{v} . \nabla \bar{v}\right) = -\nabla p + \mu \nabla^2 \bar{v} \quad (3)$$

Where: ρ - density of blood, $\bar{v}$ -velocity field, p - pressure, μ = co-efficient of viscosity.

II. METHODOLOGY

Computational fluid dynamics is utilized in numerous areas, for example, designing and therapeutic field. This new field gives detailed data about fluid qualities. Medicinal science loaned this new innovation to examine hemodynamics inside the body. In aneurysm CFD help us to comprehend their arrangement, development, and burst through investigation of aneurysm properties, for example, geometry, characteristics of blood flow such as velocity, density and viscosity.

The reason for our examination is to show the plausibility of advancement of computational investigations of patterns of streamlines, pressure, path lines and velocity. Discretization is led in Gambit. Governing equations were solved using finite volume method.

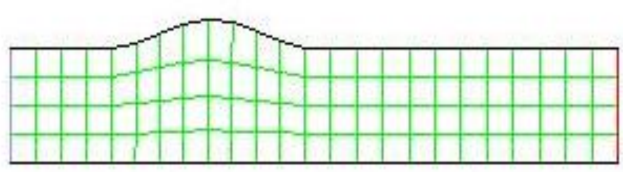

Fig. 2: Grid Display for Single Aneurysm

In reality the blood has non-Newtonian, in the simulation it is viewed as Newtonian in light of the fact that there were no huge contrasts in the appropriation of distribution of wall shear stress [7]. Normally the velocity of the blood flow is 0.344 [m/s] and top systolic drop occurs at t = 0.13 [s]

Reynolds number and Womersley number are the main two physical parameters important to understand an incompressible liquid flow problem. Womersley number (α) relies upon: stream rate, model geometry and liquid consistency and fluctuates with vessel diameter. Womersley number is: $\alpha = r\sqrt{\frac{2\pi v \rho}{\mu}}$

where: r [m]-passage of the vessel range,

υ - flow rate,

ρ [kg/m3] - blood density,

μ-[Kg/ms]-blood viscosity.

The dimensionless Reynolds number (Re) gives the flow direction. This number fluctuates with the measurement

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of the vessel for each case. $Re = \frac{\rho v d}{\mu}$

Depending on this number blood flow values in the model can be:

- Laminar when Re ≤ 2300,

- Transient when 2300 <Re <10000,

- Turbulent when Re> 10000.

If flow is laminar, Wall Shear Stress is defined as the velocity gradient at the wall, through the relation: $\tau_{w} = \mu \frac{\partial v}{\partial n}$.

where τ_w [Pa] - tension tangential to the wall, μ[kg / ms] - blood viscosity, V [m / s] - the velocity of blood flow in the vessel, N - normal direction to the vessel wall. [5]

III. Results And Discussions

The velocity and pressure of the fluid vary, through an artery that narrows or widens.The artery is approximately circular, velocity distribution is considered parabolic in the artery entry, with a maximum into the center of the vessel and a minimum close to the vessel wall . Each aneurysm has its unique hemodynamic profile, but many aneurysms have the same characteristics. The most common jet inflow had maximum collision in the aneurysm neck. After impact on the wall of the aneurysms, the inflow jet disintegrates into one or more "whirlpools", depending on the aneurysm geometry. It is observed from Fig.3 and 4 that the velocity is low near the boundary and high in the centre of the vessel. The pressure magnitude is high in the region of aneurysm, which is reverse to velocity profile are visualized in Fig. 5 and 6.

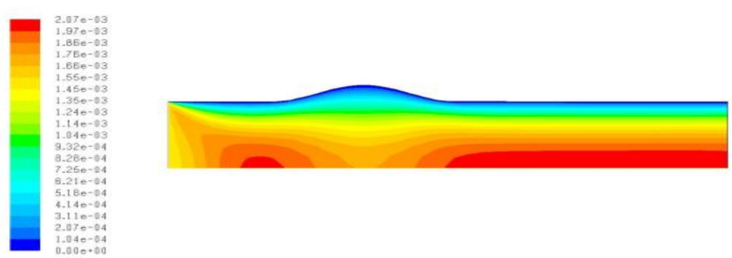

Fig. 3: Velocity Magnitude for the Velocity 0.2m/s

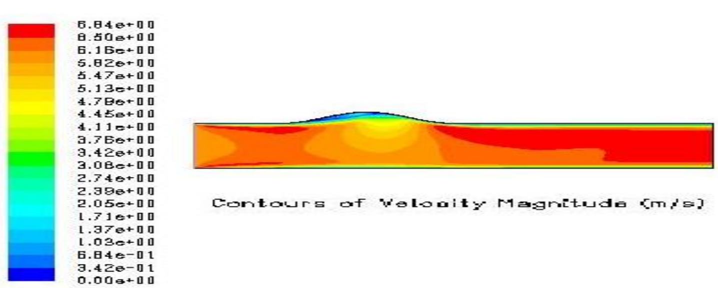

Fig. 4: Velocity Magnitude for Velocity 0.6m/s

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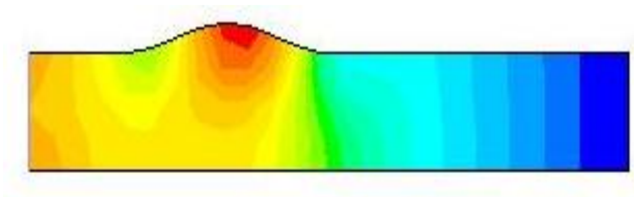

Fig. 5: Static Pressure for an Aneurysm Pressure Varies between -1.42e+02pa to 5.38e+01pa

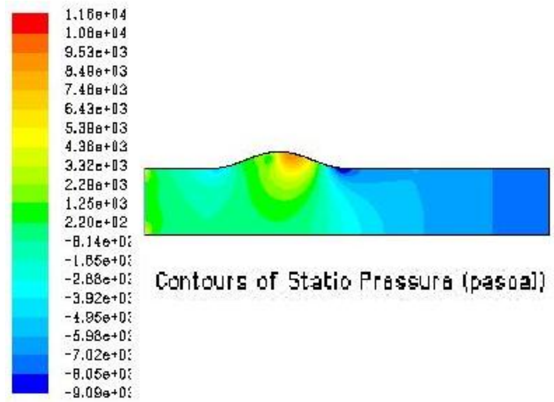

Fig. 6: Static Pressure for Velocity 0.6m/s

Streamlines are a group of curves that are instantaneously tangent to the velocity vector of the flow. These show the direction a fluid element which travels at any point at any time. These stream lines are representative of the velocity in a given time. Path lines are the trajectories that individual fluid particles follow.

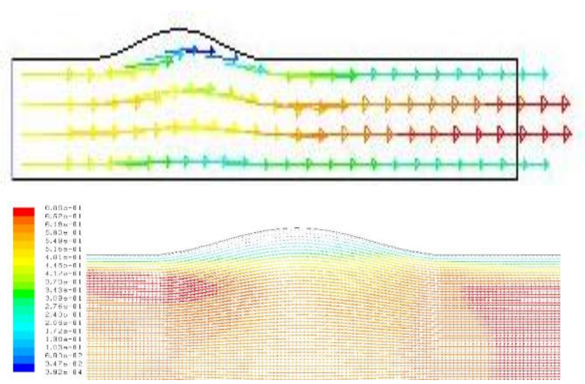

Fig. 7: Streamlines- Velocity Vectors for Single Aneurysm

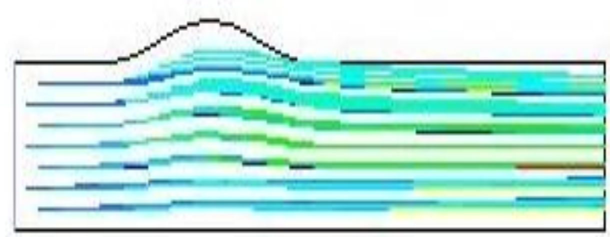

Fig. 8: Path Lines of an Aneurysm

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By considering equation of continuity (black), and momentum equation with

x -velocity(red),y – velocity(green) iterations are calculated

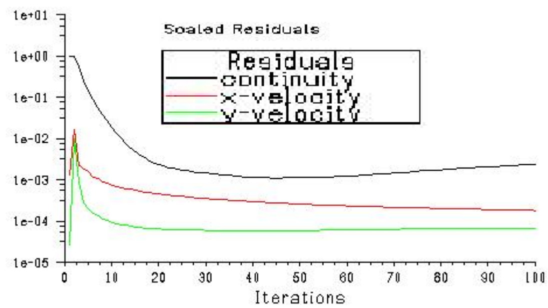

Fig. 9: Convergence of the Solution

IV. CONCLUSION

It is observed that the flow pattern is not similar in all aneurysm model but depends on the geometry of the model. Low velocity and High pressure are observed in the region of aneurysm. CFD techniques are important to study the relationship between risk of rupture and hemodynamics parameters. Further study can be made on the risk of rupture with detailed information and more data.

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DOI: 10.37200/IJPR/V24I4/PR201597
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