GENERALIZED POWER LAW MODEL OF 3-DIMENSIONAL BLOOD FLOW IN BIFURCATED STENOSED ARTERY

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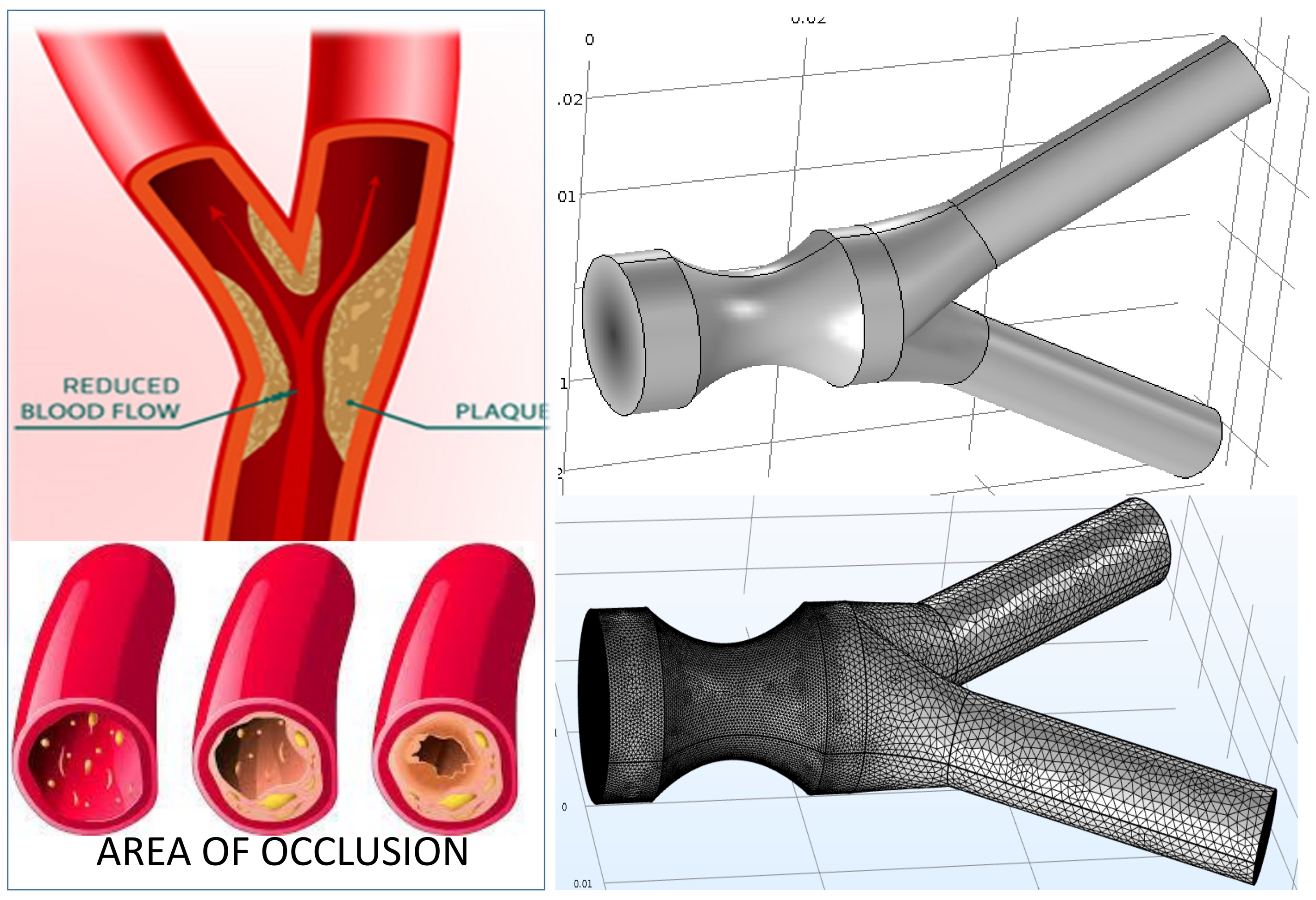
BLOOD FLOW IN BIFURCATED STENOSED ARTERY

Stenosed artery which means the artery with a blockage caused by atherosclerosis. Atherosclerotic constriction that deposit on the inner lining of the artery were made of fatty substances, cholesterol, cellular waste products, calcium and fibrin. This abnormal growth formed on the arterial lumen was belief as the main occurrence to cardiovascular diseases and mortality. As the deposited plaque grows larger, the blood passage area will be reduced and hence the normal pattern of blood flow could be distracted, Rabby, M.G et al (2014). Many of investigators have shown that blood behaves like a non-Newtonian fluid at low shear rates and some stated that blood flow in the regions of bifurcations, junctions and curvatures of large and medium arteries were exposed to either high or low shear stress which consequently affected by atherosclerosis, Ryou, H.S., and Ro, K.C (2010).

GEOMETRY AND MESH



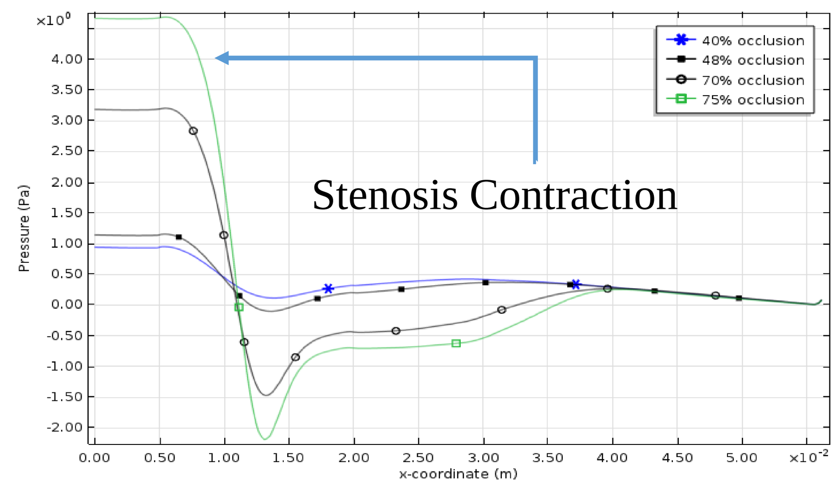


Fig 1: Pressure distribution along the vessel wall

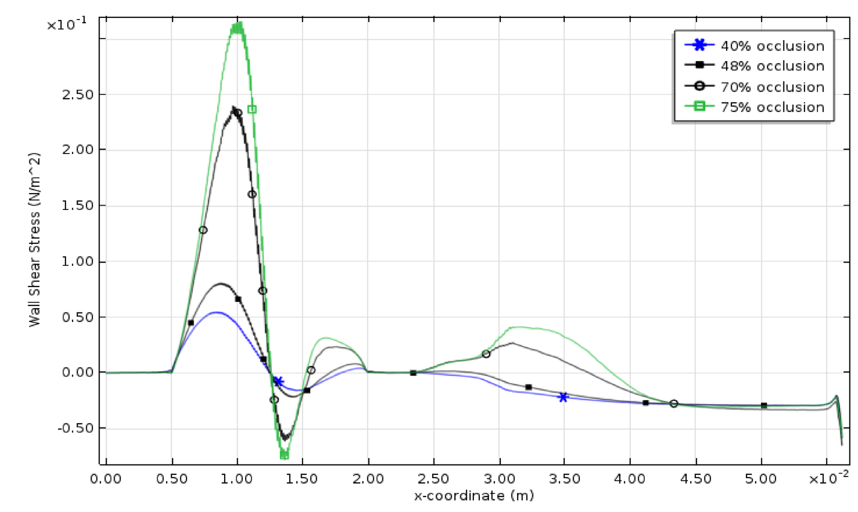
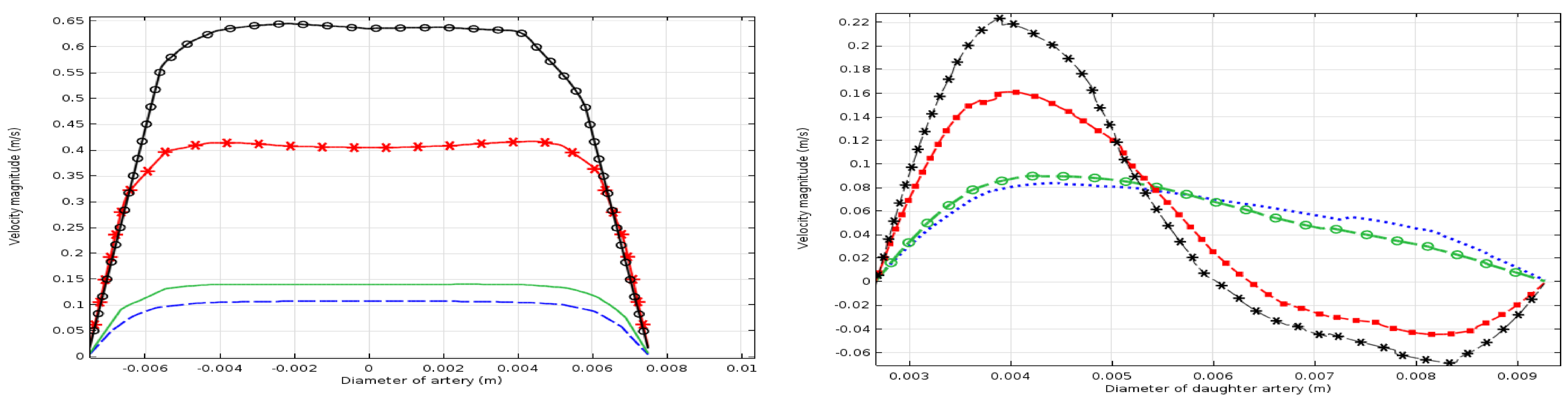


Fig 2: WSS for different occlusion of stenosis



(a) (b)

Fig 3: Axial velocity for different severity of stenosis at (a) mother artery, (b) daughter artery.

MATHEMATICAL MODEL

The governing equations and the boundary conditions Sousa, L et al. (2011) for incompressible, laminar and steady flow are given by

$$\frac{\partial(ru)}{\partial x}+\frac{\partial(rv)}{\partial y}+\frac{\partial(rw)}{\partial z}=0,$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{r}\frac{\partial p}{\partial x}-\frac{1}{r}\left[\left(\frac{\partial t_{xx}}{\partial x}+\frac{\partial t_{yx}}{\partial y}+\frac{\partial t_{zx}}{\partial z}\right)\right],$$

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{r}\frac{\partial p}{\partial y}-\frac{1}{r}\left[\left(\frac{\partial t_{xy}}{\partial x}+\frac{\partial t_{yy}}{\partial y}+\frac{\partial t_{zy}}{\partial z}\right)\right],$$

$$u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{1}{r}\frac{\partial p}{\partial z}-\frac{1}{r}\left[\left(\frac{\partial t_{xz}}{\partial x}+\frac{\partial t_{yz}}{\partial y}+\frac{\partial t_{zz}}{\partial z}\right)\right].$$

The inlet flow of the blood, Mamun et al (2016):

$$u(x,y,z)=U.\left(1-\frac{y^2+z^2}{x^2+y^2}\right),v=0,w=0.$$

The pressure point constrain is applied:

$$p=0,x=y=0,\ z=-a.$$

The velocity boundary conditions on the wall of the daughter artery are taken to be usual no-slip condition.

$$u(x,y,z)=v(x,y,z)=w(x,y,z)=0.$$

(a)

(b)

(c)

(d)

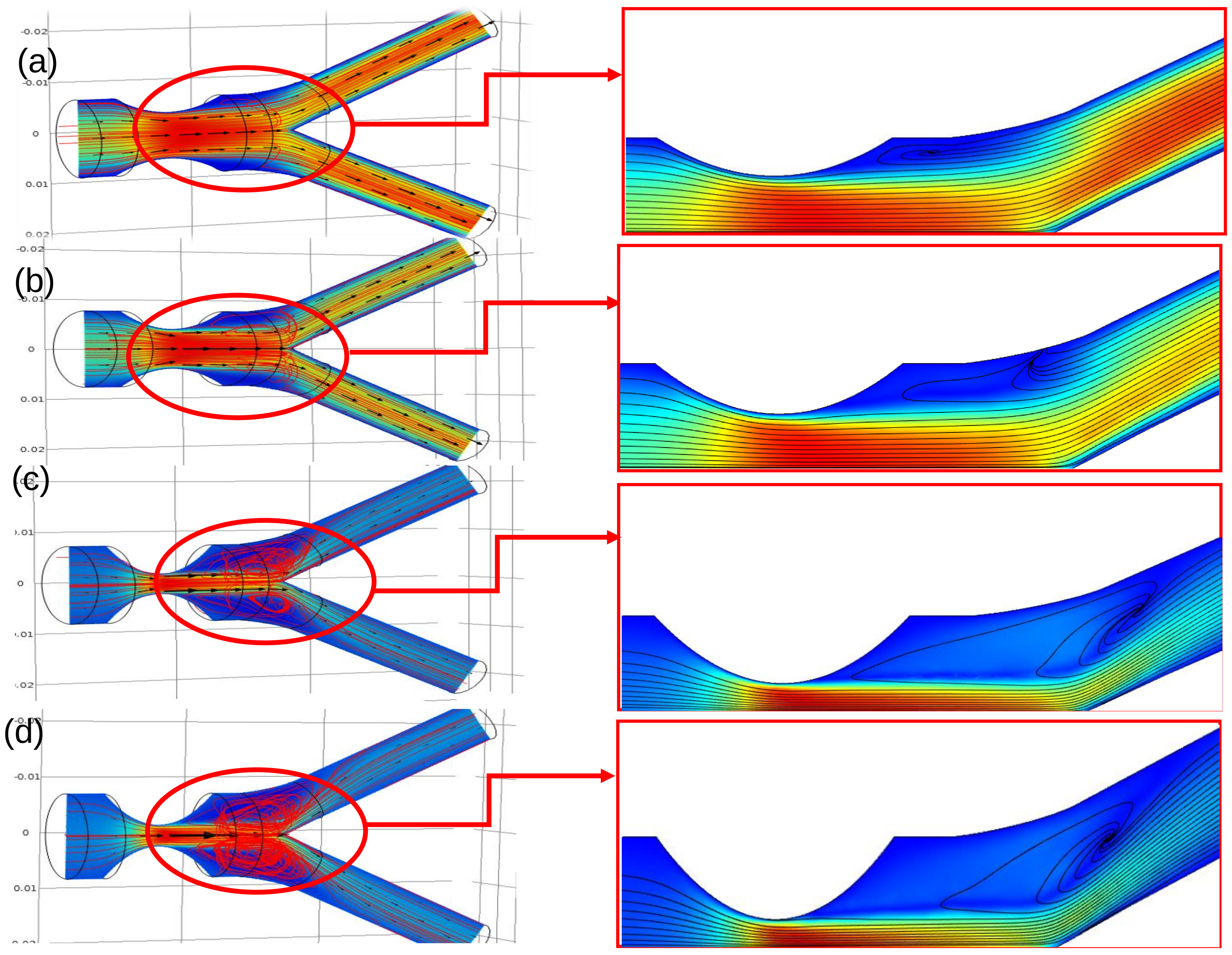


Fig 4: Velocity contour with streamline pattern for for (a) 40% occlusion, (b) 48% occlusion, (c) 70% occlusion, (d) 75% occlusion

RESULTS & DISCUSSION

The focus of discussion is on the effects of severity of stenosis. Graph of the pressure distribution, wall shear stress (WSS), streamline pattern and axial velocity are illustrate as in Figure 1, 2, 3 and 4 respectively for 40%, 48%, 70% and 75% occluded at the maximum height of mild stenosis region. Figure 1, 2, 3 shows the pressure distribution, WSS and axial velocity increases as the severity of the stenoses increases. From Figure 4, the streamline pattern clearly shown the recirculation zone at the offset of the stenosis in mother artery. Occlusion of stenotic vessel will affect the size of recirculation. The streamline pattern shows reversal are getting larger with the increment of occlusion. This increment cause the recirculation zone to elongate along the outer wall of daughter artery.

As the stenosis height enlarged from 40% to 75%, the recirculation area grows even larger. Hence, the severity of stenosis discovered to enhanced the vortex formation and may lead to a serious complication on the flow characteristics and may also trigger plaque rupture.

CONCLUSION

Numerical simulation of generalized power law model, laminar, incompressible in a stenotic bifurcated artery has been develope where the shape of the stenosis is considered mild. From the outcome, it is concluded that the peak vekocity is maximum at the most occluded region. Besides that, the increment in the severity of stenosis also demonstrate an increased of the pressure, WSS, velocity profile due to the more slender region of occlusion in the stenotic region. For future work, a compliant walls can be considered instead of a rigid wall assumption carried out for this current study.

ACKNOWLEDGEMENT

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