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ANALYSIS OF HEMODYNAMIC EFFECT ON DIFFERENT STENT STRUT CONFIGURATION IN FEMORAL POPLITEAL ARTERY FOR PHYSIOLOGICAL CONDITIONS

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ABSTRACT

Peripheral arterial disease (PAD) is a narrowing of the peripheral arteries that might result in blockage if not immediately treated. Normally, an invasive technique called stenting is used at the stenosed arterial region to restore normal blood flow. Thus, it promotes the formation of thrombosis on the stented artery due to the presenting flow recirculation. However, the rate of thrombosis growth was reported to be different for both genders. This is due to an increase in body surface area, body mass index, and weight of the body. Thus, this study aims to investigate the effect of the physiological condition of men and women with different hemodynamic parameters on the strut configuration in FPA. Five different stent strut configurations were modelled and inserted into the FPA. The computational fluid dynamic (CFD) method was implemented to solve the continuity and N-S equations. The hemodynamic performance of the stent was analysed based on hemodynamic parameters consisting of time- averaged wall shear stress (TAWSS). According to the observations, the distal region of the stented FPA had more dominant flow re-circulation than the proximal region. The high void area contributed to less growth of the thrombosis.

KEYWORD

CFD, Femoral Popliteal artery, TAWSS, Thrombosis

INTRODUCTION

The Femoral popliteal artery (FPA) is located at the limb of the lower extremity. The primary function of this artery is to carry oxygenated blood from the heart to be supplied to superficial tissues and thigh muscles (Kastrati *et al.,* 2001). The restriction of blood flow in the FPA will cause severe disease in patients known as peripheral artery disease (PAD). PAD is intimately related to chronic inflammatory processes resulting in the formation of lipid plaques or stenosis within arterial walls (Bentzon *et. al,* 2014). The standard treatment of arterial stenosis is by stenting, which effectively props open the artery and thereby restores blood flow in the diseased vessel (Chen *et. al*, 2018). However, in the first month after stent implantation, the restenosis or re-blockage in the artery has already occurred due to atherosclerosis and the growth of thrombosis (Murphy & Boyle, 2010). Atherosclerosis is the hardening of the arterial wall caused by a build-up of fatty material, while thrombosis is the formation of a blood clot within the lining of an artery, especially in a stented artery. This abnormality of blood movement makes the fatty materials deposit near the stent strut configuration. An arterial injury causes the arterial wall to undergo an episodic process of thrombus formation, arterial inflammation, neointimal hyperplasia, and stent remodeling (Cohen&DePetris, 2013).

A previous study found that a different strut arrangement accelerated atherosclerosis and thrombosis development significantly. The considerable advancement is owing to the fact that each stent has its own strut configuration, which presents variable flow characteristics near the strut (Paraskevas &Veith, 2016). Thus, the significant progress allows the hemodynamic performance of the stent to be predicted. However, Nordstrom et al mentioned that, the rate of thrombosis was different between men and women due to increased body surface area, body mass index, and weight for men than women (Nordstrom & Weiss, 2008). Hence, this study was aimed at determining the flow phenomenon near the geometrical pattern of the stent strut configuration to predict the thrombosis growth for different genders.

The flow process of this research is divided into two sections; simulation and evaluation procedures. In simulation, the simplified geometry of the FPA was developed using computer-aided design (CAD) software to predict the hemodynamic effects of the different stent strut configurations. The computational fluid dynamic (CFD) method was implemented in the modelling to predict the flow behavior by solving the continuity and Nevier-Stokes equations. The computational fluid dynamic (CFD) method could predict the potential risk of restenosis and WSS distribution in stented arteries (Gokgol *et. al*, 2019). In the second process, this study proposed a detailed analysis and assessment to predict the favorable hemodynamic stent performances among the stents by comparing the hemodynamic variable effects on five different types of commercial stent strut configurations. The hemodynamic variables considered was time-averaged wall shear stress (TAWSS).

MATERIAL AND METHODOLOGY

The simplified geometry of the FPA artery was developed using the computer aided design (CAD) software SOLIDWORK (Dassault Systèmes SolidWorks Corporation, Waltham, Massachusetts, United States). This model has a length (L) of 109 mm between of proximal and distal end and the diameter (d) of 7.4 mm as shown in Figure 1. The simplified of the FPA was modelled based on the previous finding by Kaha *et. al*, (2018).

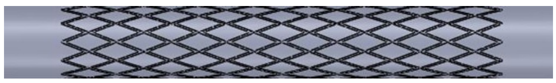

Figure 1: Simplified Femoral Popliteal Artery (FPA)

In this study, several parameter assumptions were considered in the stented FPA simulation. The assumptions parameters were considered as fluid having a constant density of 1060kg/ m^3 and viscosity of 0.0035 *kg/ms* (Kaha *et. al,* 2018). Since the present study is turbulence, Newtonian blood model is a reasonably good approximation when studying the wall shear stress distribution. On the solid arterial walls, no-slip boundary condition is imposed. In order to simplify the simulation, the walls of FPA models was assumed rigid as it do not affect the output results significantly.

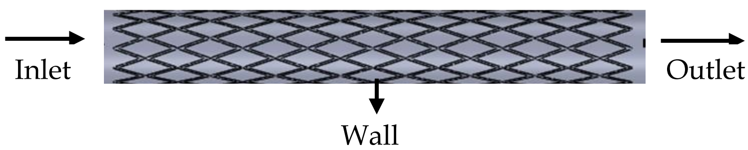

Figure 3: Boundary conditions of stented femoral popliteal artery model.

From the observation, the suitable numbers of nodes were found at the 532643 nodes. This is due to the smaller error calculated within the range of 400k to 600k. The calculated error was less than 5% the range of the nodes was acceptable as shown in Figure 4. In this study, the validation was carried out by validating the streamline of flow velocity in Femoral artery between the present numerical and experimental data by Giurgea *et. al*, (2014). The relative error was 2% between the current and previous study as shown in Figure 6.

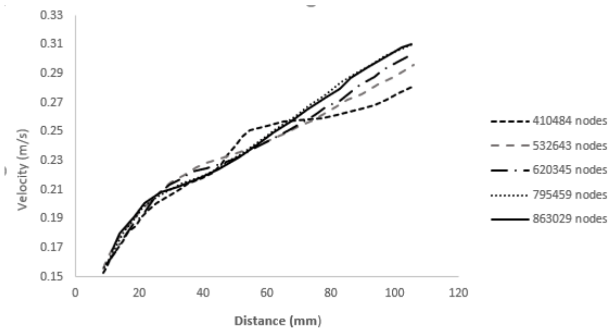

Figure 4: Grid Independence test

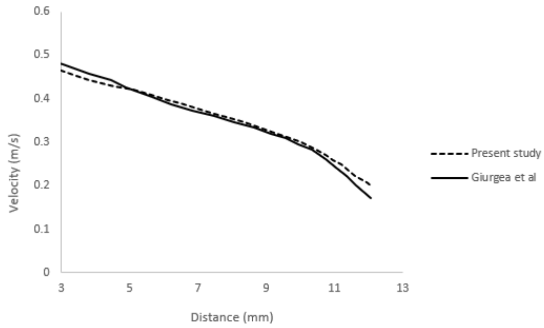

Figure 5: Validation

RESULT AND DISCUSSION

The movement of the blood passing through the corrugated stented FPA caused the chaotic flow characteristic especially near to strut configuration. This phenomenon is caused by WSS which is theimportant hemodynamic parameter being used to predict the growth of thrombosis. The time- averaged wall shear stress (TAWSS) was introduced to facilitate the quantification and finally predictthe hemodynamic stent performance. A flow with a high TAWSS more than 3 Pa can lead to endothelial trauma, hemolysis, plaque destabilization and ulceration in stenosed vessel (Wang *et. al*, 2021). Thus, in this study, analyzed of the $TAWSS_{low}$ and $TAWSS_{high}$ for the value less than and higher than 1 Pa and 3 Pa respectively. Any value in between 1 Pa and 3 Pa considered as $TAWSS_{normal}$ (Razhali & Taib, 2022).

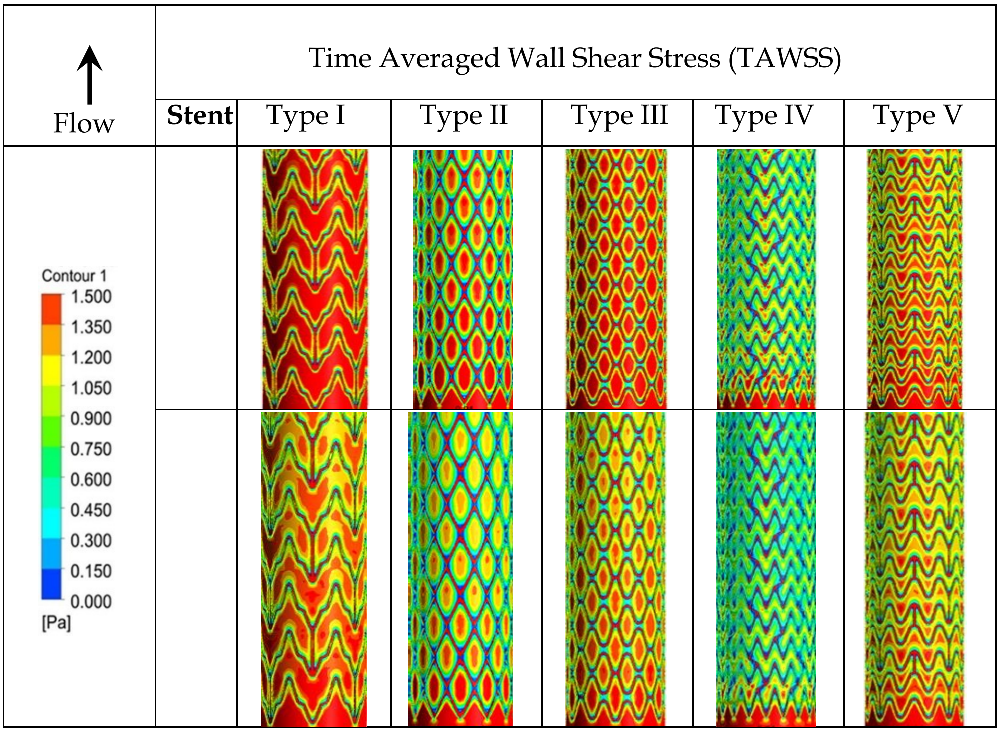

Figure 6: TAWSS distribution at stent strut configuration for men and women

CONCLUSION

In conclusion, the research on investigating the analysis of hemodynamic effects on different stent strut configuration in Femoral Popliteal artery has been successfully carried out. The best stent performance configuration is Type I. Type I stent has high void area contributed to less growth of the thrombosis as compared to the other stent. Thus, this study achieved the aims to investigate the effect of the physiological of men and women with on the strut configuration in femoral popliteal artery.

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