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Study of Anastomosis Obtuse Angles to Reduce Fistula Failure with Numerical Simulation

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ABSTRACT: Regarding the major determinant of Anastomosis angle in the efficiency of fistula for dialysis, obtuse angle Anastomosises are designed and simulated with angles of 90, 120, 135 and 145 degrees and the obtained results are evaluated from the standpoint of flow patterns at the region of the Anastomosis and shear stress in the fistula wall. In this study, in order to compare obtained results in fistula, two Newtonian and carreau non-Newtonian blood models are used at maximum and medium flow rate of blood pulsation curve (in flow rate at the time of 0.2 and 0.4 seconds respectively). At an angle of 90 degrees, the formed vortices dimensions, due to the separation of the flow during passing through the region of the Anastomosis, significantly larger than obtuse angles. Consequently, the probability of deposition in the region of the flow increases sharply. So from the standpoint of flow pattern, the 90-degree angles are inappropriate Anastomosis angle for fistula. At the obtuse angles, the dimensions of these vortexes become much smaller, and then the obtuse angles are considered a better choice. From the standpoint of maximum shear stress, Anastomosis with obtuse angles in comparison with the Anastomosis angle of 90 degrees, has lower maximum shear stress values and the range involved in the maximum shear stress in Anastomosis with 90 degrees is much wider than the range of Anastomosis with the obtuse. Hence, the probability of manifestation of thrombosis (the main factor of fistula failure) is much higher. In this simulation, the results related to the Newtonian and non-Newtonian models are very close, and the non-Newtonian model predicts shear stress slightly more.

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1- Introduction

Currently, an arteriovenous fistula is the best choice for longtime vascular access to dialysis [1]. Using of fistula for dialysis was firstly suggested in 1973 by Karmody and Lempert [2] and usually used from the radial artery and the cephalic vein located on the wrist to create it [3]. It has been shown that after a time of anastomosis, blood flow to the fistula is reduced. Theoretical and experimental studies have shown that high shear stress causes thrombosis and low shear stress causes vortices and causes cramps in the flow area [4]. According to the research background, the type of anastomosis angle can have a significant effect on fistula performance, such as cramps and thrombosis. In this paper, the 90, 120, 135 and 145 degrees anastomosis angles are studied in the maximum and medium flow rate of blood pulsation curve. For modeling, the arteries 2 mm in diameter, the veins 3 mm in diameter and the distance between the central axis of the arteries and veins 8.5 mm in length, is used.

2- Methodology

2- 1- Equations

The main equations used for simulation are continuity and momentum equations. For turbulence modeling, the SST-kω method is based on the Reynolds averaged method and the corrected version of the standard model provided by Wilcox was used [5]. The flow is incompressible and, for comparison, two types of Newtonian and non-Newtonian blood with carreau model are used [6-8].

2- 2- Numerical method

In the present simulation, the first-order Euler's method for time termes and the limited linear combination method [9, 10], for convection terms, momentum transfer equations, k and ω, and the second-order central method for diffusion terms are used. Designed geometries were simulated using a pimplefoam solver, which is a Transient solver for an incompressible flow [11]. For boundary conditions, the maximum and medium flow rate of blood pulsation curve [12] (in flow rate at the time of 0.2 and 0.4 seconds respectively) were used.

3- Results and Discussion

The flow pattern in the two Newtonian and non-Newtonian models is very similar, but the non-Newtonian model predicts higher shear stress values. With increasing the angle of the anastomosis of 90 to 145 degrees, the maximum shear stress

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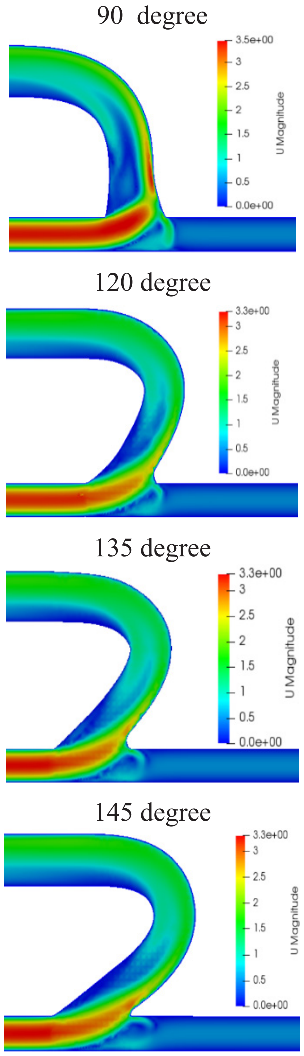
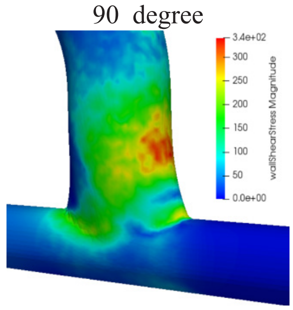
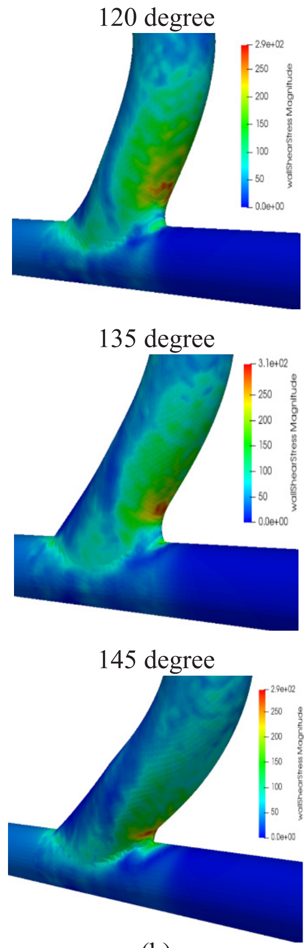
reaches from 327 to 280 Pascal (angle respectively), and in the non-Newtonian model, these values reduce from 334 to 287 Pascal.

Fig. 1 shows the velocity and shear stress contour in the maximum flow rate. As can be seen, the anastomosis with 90 degree angle has the highest maximum shear stresses. Also, at this angle, the range involved in the maximum shear stress is larger on the fistula wall, and it can be said that the probability of spreading thrombosis is greater at a 90 degree angle.



(a)





(b)

Fig. 1. (a) The velocity contour and (b) The shear stress contour for different anastomosis angles with the carreau non-Newtonian model in the maximum flow rate

4- Conclusions

The results of the Newtonian and carreau non-Newtonian model are not significantly different. Corresponding to the flow pattern, it can be said that the anastomosis with 90 degree angle is not an appropriate angle to create a fistula, because the probability of sediment and the reduction of blood flow to the fistula is higher. Also, at this angle, the range involved in the maximum shear stress is larger on the fistula wall, and it can be said that the probability of spreading thrombosis is greater at a 90 degree angle. Finally, it can be said that the anastomosis with obtuse angles is more suitable for fistula creating.

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