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CHARACTERIZATION OF BLOOD FLOW IN VISCOELASTIC CAPILLARIES BY NUMERICAL SIMULATION

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ABSTRACT:

The current paper studies the Numerical enquiry of red blood cells which is symmetric with respect to its axis, pressure driven motion of single file which hangs the flowing in capillaries of diameter 7-12 µm. Our study creates such important in vivo dynamics of blood flow dynamics of blood flow also some hemorheo logical characteristics of microscopic blood flow including such cells having shape of parachute, its blunt velocity and fahraeus effects and they shown to have strong dependence on cell deformability, hematocrit and vessel size.

Keywords- *hematocrit, deformability, fahraeus effect,numerical,hemorheological*

INTRODUCTION:

The study of dynamic blood flow and red blood cells in capillaries is show a great importance because they give major site of oxygen and exchange of Nutrients in capillaries, blood seen in the form of suspension of red blood cells in plasma because of its high volume friction. It is also investigated that the dynamic capillary flow is affected by red blood cells arrangement, orientation and its deformability in the suspension of plasma. Counting 6-10 µm in diameter there are a smallest capillaries in the form of blood vessels in the body of human.

The average size of general cells having red colour is 7.5 µm in diameter and it changes its size with respect to its thickness which ranges from∽ 2.5 µm at the rim to ∽ 1.6 µm at the centre. In the absence of flow they considered as biconcave disc shape. The cell membrane of RBC's show highly deformability, they also show axisymmetric Parachute Shape like structure which helpful for reduction in the flow of resistance which also leaves a plasma which is cell free layer between RBC & vessels wall [1-2]. The deformability of RBC is critical determinant of blood flow in capillaries and is the combined result of several mechanical and physiological properties. The important properties of blood is hematocrit which stated the volume fraction of Red blood cells to the total blood volume and it changes from 28 to 40%, 36 to 47%, for child adults. The fahraeus effect [3] is the properties of reduction of tube hematocrit and discharge hematocrit (HD) which seen in micro vessels the observation of this effect is due to mean velocity of RBCs which was maximum as compared to the bulk flow velocity [4] and it is also observed that the ratio of these velocities decreases with increases hematocrit. The application of blood flow dynamics in mathematical and numerical models have been detect to provide useful information on the dynamic properties of blood flow under complex flow conditions.

When, the blood flow in both sized of vessels i.e. in big and medium that fluid is well approximated by continued medium similarly to obtain the information about flow of blood in capillaries.Thetwo assumptions are must be considered in the numerical simulations from which first is that multiple cell which show cell to cell hydrodynamic interaction due to maximum hematocrit condition and the second is that the deformation of the cells which is considered in the form of model the Tsubota etal [5] carried out a numerical study on the effect of hematocrit on the blood flow properties in a two dimensional channel. Using partial Method of suggested that shape of red cells and the flow in capillary is significantly affected by hematocrit level.

The main Aim of this studies that to predict the blood flow properties in capillaries using numerical methods. We represent two-dimensional computational simulations of blood flow in vessels of diameter 8-11 [6-9] µm at H_T of 11- 40% taking into consideration on the particulate nature of blood and cell deformation. The simulation is based on numerical solutions of the aspects about the effect of parametric simulation of hematocrit, its deformability and the size of vessels.

NUMERICAL SIMULATIONS & DISCUSSION:

Due to the size of Red blood cells as compared to the vessels in capillaries the blood is supposed to be multiphase fluid. It is arises that the flow dynamic in capillaries show same to that of suspension of deformable particles. It is also observed that the component of liquid which is in blood and its cells are suspended is mainly composed of water in large extent which was depends on plasma of Blood.

For the incompressible Newtonian fluid the flow of plasma in capillaries is supposed to be organised by Navier stokes equation.

$$\rho\left[\frac{dy}{dt}+u.\nabla.u\right]=-\nabla p+\mu\nabla\mu+f \text{ -------------------- (1)}$$

$$\nabla.u=0 \text{-------------------- (2)}$$

Where,

U = fluid velocities
P = pressure
ρ = fluid densities
µ = fluid viscosity.
f = external force applied on body.

The newly changed shape of red blood cells is modelled by the elastic spring model. This model cheack and applied to the number of blood vessels [8-9] it also have ability to capture the deformation of RBC's under different flow conditions [8-9] which is fundamental to the successful simulations of the flow behaviour the cell membrane have ability he resist to changes in area and deformation. It also show recovery to the initial biconcave shape after the removal of external flow field [9] the motion of the deformable cells and fluid domain are coupled together by the immersed boundary method [12] which stated in App B. This method is an innovative approach to deal with the problems of modelling fluid flows interacting with a flexible elastic boundary.

For a simulation the red blood cells are suspended in blood plasma which is assumed to be incompressible Newtonian and has density $\rho=1.00$ g/cm^3.

The viscosity ratio which described the Viscosity contrast of fluid inside and outside the RBC membrane which is fixed of 1.2 the fluid domain is a two dimensional channel of horizontal length up to 22 to 26 µm. The width of channel is varied from 7µ to 10 µm

Parameters of Simulation:

Mass of membrane (m) = 2.0 x 10^{-3}g
Membrane viscosity (ϒ) = 8.5 x 10^{-6}g Ns/m
Penalty coefficient Ks = K_b x 10^4
Spring Constant $K_l = K_b$

Thebending constant is closely related to rigidity of the membrane. In this the constant pressure is applied to obtain poeseuille flow. The evaluation of the periodic file of cells from a specified initial configuration with uniform all cells spacing is computed.

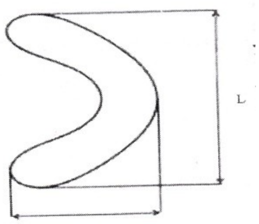
RBC DEFORMATION:

The deformation of RBC in plasma flow with varying hematocrit, Cell deformability and vessel diameter is studied in the current study cell deformability and vessel diameter studied. Stimulations are conducted in the channel as the flow starts the RBC charges quickly from its static biconcave shape to parachute shape and at the mean time RBC's move down stream with an increasing velocity. The change of shape stops when the hydrodynamic force is balanced by elastic force of the cell membrane and the cell velocity becomes constant. The equilibrium shape strongly depends on hematocrit and deformability of cell membrane.

We also study that how the shape of red cells is affected by the factors such as hematocrit the vessel diameter and the deformability of the cell for this the equilibrium length L of the cell and the deformation index DI defined as-

$DI=\frac{W}{L}$

L and W are shown in figure.



The equilibrium length L is platted versus hemotocrit for the channel width D=8.9, 10 f=11 µm

The length L increases almost linearly with the increase of H_T over the same range for these vessels. In the current paper it is also investigated that the impact of deformability of the membrane on size red cell in the blood flows.

BLUNT VELOCITY PROFILE:

Comparing to the parabolic profile of the poiseuille flow for the pure plasma the velocity is flat topped in the centre region for the blood flow in capillaries containing Red Blood Cells under the same pressure gradient. The effect of hematocrit, deformability of the cell and vessel size on the velocity profile has been found in current work. The maximum velocity at the centreline decreases rapidly when more RBCs are present when the tube hematocrit reaches 41.% of that pure plasma. It is also observed that the flow profile is less blunt with the increase of RBC deformability the distribution of axial velocity in the change of deformability than the hematocrit of the blood. Since the decreased in blunt flow the radius causes the reduction in resistance to flow we can conclude that RBC flexibility plays important role in reducing the flow resistance of blood in capillaries.

It is also observed that as compared to the flow in 10µm capillary. The flow in the 8µm capillary is less deviated from pure plasma poiseuille flow for H_t=10% and more blunt for higher hematocrit value. The reason is that in a narrow capillary with the same hematocrit the intercellular space between two neighbouring cells in larger, which allows the flow to develop more fully than in wider capillary however this effect is only significant when the hematocrit is low as the hematocrit becomes higher, the flow is severally blunted by the increasing number of cells in the vessels.

THE FHAHREUS EFFECT:

To capillary vessels the red cells speed up relative to the plasma as they squeeze through the capillary. Since they must travel faster than the plasma, there must be fewer of them present to maintain the same proportion of cells and plasma as blood exits the capillary this is the fahraeus effect. The reduction of tube hematocrit H_T to discharge hematocrit H_D due to the Fahraeus effect is related to the means flow velocity Um and the Velocity Uc. $\frac{H_t}{H_d}=\frac{U_m}{U_c}$. It is also seen that H_T was used as a control parameter. The hematocrit ratio is also strongly related to the deformability of the red cells. Also the hematocrit ration is found to decrease linearly with the increase of deformation.

CONCLUSION :

In the currentstudy the simulated the dynamics of the blood flow and RBCs in capillary using a numerical approach the result show that RBCs in narrow capillaries change to parachute shape in the flow field the profile of the capillary flow was markedly blunt in comparison to the parabolic one which characterized the pure plasma flow the hematocrit ratio reduces from the value of unity in these capillary our study shows that the RBCs shape, bluntness of the flow profile and the reduction of the hematocrit ratio are strongly depend on the tube hematocrit, deformation of the cell and the size of the vessel. We also observed that the distribution of axial velocity in the capillary is more sensitive to the change of hematocrit than the deformability of the cells. The result indicates that the pressure difference in the blood flow has to increase in the capillary vessels in order to sustain the same flux rate of red blood cells when the hematocrit increases.

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