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Editorial

Hemorheology: Capturing the fluid dynamics of blood

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Rheology is the study of flow and deformation of materials under applied forces. It is primarily applicable to liquids but is also applicable to soft-solids, semi-solids and even solids under conditions in which they respond with plastic flow **[1]**. It includes the phenomena of flow of solids, liquids and gases; and particularly involves time-dependent behavior under the influence of stresses **[2]**. The application of rheology extends to materials having complex microstructure like mud, sludge, suspensions, polymers, silicates, body fluids, etc. Rheology describes the behavior especially of non-Newtonian fluids wherein viscosity changes with change in strain and flow velocity **[1]**.

Flow is typically measured using shear stress (τ) i.e. stress component coplanar with the material cross section and strain rate (γ) i.e. deformation of material with respect to time. Viscosity (η) is calculated as the ratio between sheer stress and strain rate **[3]**.

$$\tau = \frac{Force\ applied}{Cross - sectional\ area\ of\ material}$$

$$\gamma = \frac{Change\ in\ dimension}{Change\ in\ time}$$

$$\eta = \frac{\tau}{\gamma}$$

Among body fluids, blood is the best example of non-Newtonian fluid. It is a non-homogenous fluid suspension having plasma with all its dissolved solutes acting as fluid base in which formed elements and large protein molecules are suspended.

Hemorheology is very peculiar as the formed elements have great flexibility and blood flows in compliant vessels. The viscosity is also optimal owing to presence of glycocalyx on the surface of the blood cells and the endothelium.

Blood flow almost all the time in most of the vascular tree is laminar (streamline) due to many factors inherent to components of blood and vessel walls. The probability of turbulence increases with increase in velocity of blood, increase in diameter of vessel and decrease in viscosity. Hyperdynamic circulation with increased turbulence may physically damage the endothelium. On the other hand, sluggishness (decrease velocity) of blood flow and increase viscosity predisposes to thrombus formation.

Studies have shown association of various disordered states with the changes in physical properties of blood **[4]**. Blood pressure increases with increase in blood viscosity **[5]**. Plasma viscosity and RBC aggregation showed significant association with cardiovascular disease (CVD) **[5,6]**. Increased hematocrit and fibrinogen resulting in increased blood viscosity may promote ischemic heart disease (IHD) and stroke **[7]**. Also rheological variables especially blood viscosity showed significant correlations with conventional cardiovascular risk factors like

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cigarette smoking, advancing age, hypertension, high body mass index and serum total cholesterol **[8,9,10]**. Increased plasma viscosity is associated with decreased cognitive ability in diabetes possibly by decreasing cerebral blood flow **[11]**.

Now the question arises – 'Do rheological variables play a causal role in disease?'. Rheology is an overlooked component of vascular disease **[12]**. The plausible pathophysiological mechanisms by which rheological variables might promote CVD are atherogenesis, thrombosis or perpetuation of ischemia. Increase in blood viscosity increases total peripheral resistance thereby raising blood pressure. It cannot be told with certainty that the association of rheological variables with CVD may be a causal relationship or a consequence or a mere coincidence and needs larger randomized controlled studies for confirmation **[4]**. However, the importance of the rheological measures in CVD cannot be ignored as raised blood viscosity leading to high vascular shear stress contributes to the site specificity of atherogenesis, rapid growth of atherosclerotic lesions and increases their propensity to rupture **[13]**. Therapeutic intervention in the form of statin administration targeting reduction in serum lipoproteins significantly reduced both plasma and blood viscosity **[14]**. Drugs like dihydropyridine calcium antagonists improve red blood cell deformability thereby improving blood rheology **[15,16]**.

Therefore, enough evidence to show that the rheological parameters of blood should also be accounted for apart from hemocytometry and biochemistry in determining the risk and in the prognosis of a disease condition particularly in IHD and stroke. Hence, *"capturing the fluid dynamics of blood"* may play a considerable role in clinical medicine.

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