A STUDY ON RHEOLOGICAL DISORDERS OF DIABETIC BLOOD, PLASMA AND ERYTHOCYTES

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ABSTRACT

Blood is a vital fluid found in human beings and other animals. It is a mixture of cells and watery liquid, called plasma. Since blood is viscous by nature ie the thickness and stickiness of an individual's blood is associated with many risk factors of health of a human being. Therefore understanding the viscosity of blood, plasma and RBC and how it affects the arterial walls in normal and diabetic patients is useful to preserve and save one's life.

In this study a simple technique is used to find out the viscosity of diabetic blood, plasma and RBC at different flow rates by using normal capillary tube. The tool is developed based on the Poiseuille's theory to measure the coefficient of viscosity and volume flow rate of blood,plasma and RBC for different radii The data is presented and findings and conclusions are drawn from the data**.**

Key Words: Rheology, viscosity, Flow rate, Diabetes mellitus

INTRODUCTION

Rheology is the study of the flow and deformation behaviour of materials. It is a specialized part of fluid mechanics and is concerned primarily with non-Newtonian substances like Blood.

From a hemorheological point of view fluids can be divided into two types as Newtonian fluids, and Non-Newtonian fluids, based on the molecular composition, cellular constituents and diameter of tube (blood vessel) where it is flowing.

A Newtonian fluid is a fluid where the shear stress and strain rate is linear and passes through the origin. The coefficient of viscosity is constant. Water is an example of Newtonian fluids. A Non-Newtonian fluid is a fluid whose flow properties are not described by a single constant value of viscosity. Many common substances like ketchup, starch suspensions, paint, **blood** and shampoo come under non-Newtonian fluids.

Blood can be considered as a tissue that consists of Red Blood Cells (RBC); White Blood Cells (WBC); and Platelets. Red blood cells are more in the blood, which carry oxygen from the lungs to the body tissues. White blood cells are mainly responsible for disease prevention and immunity; and platelets are key elements in the blood clotting process. All these elements of blood are suspended in blood plasma, which is a yellowish liquid that occupies about 55% of human blood.

Viscosity is a measure of the resistance of a fluid, which is being deformed by either shear stress or tensile stress. In other words, Viscosity means the degree of stickiness of a liquid. The viscosity of healthy blood is low, therefore it flows freely. High blood viscosity slows down the circulation and reduces oxygenation of tissues.

Blood viscosity is determined mainly due to hematocrit levels, plasma viscosity and the deformability and aggregation of RBCs (Red Blood Cells). Under normal physiological conditions viscosity of blood varies because of many factors like gender, geography and heredity, and the other important factor that influences the blood viscosity is temperature. As temperature increases the viscosity decreases.Under pathological conditions the change in blood viscosity is mainly due to changes in the shear stress imparted by blood flow due to which the circulatory system and related tissues and organs damage. Plasma viscosity is determined by the concentration of plasma proteins, but the erythrocytes deformability and aggregation vary with different blood shear rates. Therefore erythrocyte with high shear rates is a major determinant of viscosity of blood

The flow rate of blood also affects viscosity. At very low flow rates in the microcirculation the blood viscosity can increase significantly. This is because at low flow rates there are increased cell-to-cell and protein-to-cell adhesive interactions which cause erythrocytes to adhere to one another and increase the blood viscosity.

Blood rheology became an important contributory factor to diabetes mellitus. Diabetes is a condition in which the body does not properly produce or utilize insulin which is the hormone that is responsible for regulating glucose entry into cells throughout the body)

Diabetes is also an important factor in accelerating the hardening and narrowing of the arteries**. Diabetes** is a chronic medical condition, although it can be controlled, it lasts a lifetime. Over time, diabetes can lead to blindness, kidney failure, and nerve damage. These types of damage are the result of damage to small vessels, referred to as micro vascular disease.

MATERIALS AND METHODS

To study the rheological behaviour of blood, a simple capillary technique is used. Though Capillary viscometry is the most traditional method for measuring the viscosity of the viscous materials, here in the present study, an open-end capillary viscometer is used and a theory is developed based on the Poiseuille's theory for the dynamics of a liquid column in an open capillary tube. No external pressure is applied on the liquid column. The pressure at the two ends of the capillary tube is the atmospheric pressure.

The simple capillary viscometric technique, which is employed in this study, is used to measure both viscosity and volume flow rate. The blood samples were collected from the patients suffering from diabetes mellitus. The samples are collected in siliconised bottles with EDTA (Ethylene Diamine Tetra Acetic) anticoagulant in the powder form.

The diabetic patients were in the age group of between 35 to 65 years, and are suffering with diabetes since 2 to 5 years. The samples for the study are collected in fasting status of fasting sugar.

Plasma was separated from blood by centrifuging the blood at the rate of 1500 rmp about 10 to 15 minutes. By taking out the plasma, RBC (90% packed erythrocytes) were separated. Blood samples were prepared by mixing an equal amount of plasma and erythrocytes. By this process, Hematocrit of sample is maintained to be constant.

EXPERIMENTAL PROCEDURE

The open-end glass capillary tube was marked with two preset points A and B and the distance between them is 10cm. It was clamped vertically to a stand. A sample of blood of length 2 to 8cm was sucked by one end of the capillary tube. The pinchcock arrangement controls the movement flow of liquid column between the preset terminals. The vertical clamping of the capillary tube with sample will set the liquid column into one-dimensional motion. At the beginning of the experiment, meniscus of column was set above the marked point A (upper mark). The timer was switched on the moment the meniscus of the liquid column passed the mark A, when the pinchcock was released. The timer was switched off now the meniscus passed off mark B (lower mark). The timer records the time of the sample, which travelled 10cm distance. The velocity was calculated from the ratio of the preset distance (10cm) and time. For different lengths of the liquid column, the time of travel was recorded and velocity was calculated. A plot was drawn between L^{-1} on X-axis and V on Y-axis. The plot is a straight line with an intercept on Y-axis. The intercept of the straight line was measured which gives the maximum velocity. Viscosity and volume flow rate of the sample were calculated from the intercept of the straight line, respectively, with the known radius of the capillary tube (R). The radius of the capillary tube (R) was measured using a travelling microscope having Least Count (L.C) of 0.001 cm.

Table-1 shows the data on coefficient of viscosity of Diabetic blood. The fresh samples of blood were collected and found the viscosity for four different radii i.e. 0.029cm, 0.040cm, 0.045cm and 0.055cm of capillary tubes. It is observed from the table that the coefficient of viscosity increases as the radius of the capillary tube increases.

CT1= Capillary Tube 1; Radius= 0.029cm

CT2= Capillary Tube 2; Radius=0.040cm
CT3= Capillary Tube3; Radius=0.045cm
CT4=Capillary Tube4; Radius=0.055cm

Table – 1: Data on coefficient of viscosity of Diabetic Blood

Sample Code	Viscosity, η (poise)			
	CT1	**CT2**	**CT3**	**CT4**
DB1	0.021	0.024	0.024	0.031
DB2	0.024	0.026	0.028	0.032
DB3	0.021	0.025	0.028	0.031
DB4	0.029	0.035	0.036	0.042
Mean	**0.024**	**0.028**	**0.029**	**0.034**
SDV ±	**0.0038**	**0.0051**	**0.0050**	**0.0054**

DB=Diabetic Blood

Table-2 presents the data on coefficient of viscosity of plasma of Diabetic blood. Four different capillary tubes of different radii i.e. 0.029cm, 0.040cm, 0.045cm and 0.055cm were taken to find out the coefficient of viscosity. By centrifuging the blood samples for 15 minutes the plasma was separated and found the viscosity. It is evident from the tables that the coefficient of viscosity increases as the radius of the capillary tube increases.

Table - 2: Data on coefficient of viscosity of Plasma of Diabetic Blood

Sample Code	Viscosity, η (poise)			
	CT1	**CT2**	**CT3**	**CT4**
DP1	0.008	0.011	0.013	0.016
DP2	0.007	0.009	0.011	0.015
DP3	0.008	0.011	0.014	0.018
DP4	0.007	0.009	0.011	0.017
Mean	**0.008**	**0.010**	**0.012**	**0.017**
SDV±	**0.0006**	**0.0012**	**0.0015**	**0.0013**

DP=Diabetic Plasma

Table-3 gives the data on coefficient of viscosity of 90% packed erythrocytes of Diabetic blood. For different radii i.e.0.029cm, 0.040cm, 0.045cm and 0.055cm of four capillary tubes the coefficient of viscosity was found. The erythrocytes were separated from plasma and found the coefficient of viscosity. It is noted from the tables that the coefficient of viscosity increases as the radius of the capillary tube increases.

Table - 3: Data on coefficient of viscosity of 90% packed erythrocytes of Diabetic Blood

Sample Code	Viscosity, η (poise)			
	CT1	**CT2**	**CT3**	**CT4**
DE1	0.043	0.047	0.064	0.073
DE2	0.064	0.076	0.077	0.091
DE3	0.047	0.064	0.08	0.092
DE4	0.049	0.065	0.073	0.087
Mean	**0.051**	**0.063**	**0.074**	**0.086**
SDV±	**0.0092**	**0.0120**	**0.0070**	**0.0088**

DE=Diabetic 90%packed Erythrocytes

Table- 4 gives the data on volume flow rate of Diabetic blood. Here also four capillaries with different radii i.e.0.029cm, 0.040cm, 0.045cm and 0.055cm were used respectively for different samples of blood and the flow rate was found. It is seen clearly from the table that the flow rate increases with the increases of the radii of capillary tubes.

Table - 4: Data on Volume flow rate of Diabetic Blood

Sample Code	Volume flow rate, Q (cm3 sec-1)			
	CT1	**CT2**	**CT3**	**CT4**
DB1	0.007	0.031	0.043	0.072
DB2	0.008	0.037	0.049	0.056
DB3	0.008	0.039	0.048	0.077
DB4	0.008	0.017	0.025	0.038
Mean	**0.008**	**0.031**	**0.041**	**0.061**
SDV±	**0.0005**	**0.0099**	**0.0111**	**0.0176**

Table-5 tells the data on volume flow rate of plasma of Diabetic blood. Plasma is separated from the blood by centrifuging the blood sample for 15 minutes. Four capillary tubes with different radii i.e.0.029cm, 0.040cm, 0.045cm and 0.055cm were taken to find out the volume flow rate of plasma. Here it is observed that the volume flow rate increases as the radii of capillary tube increases.

Table - 5: Data on Volume flow rate of Plasma of Diabetic Blood.

Sample Code	Volume flow rate, Q (cm3 sec-1)			
	CT1	**CT2**	**CT3**	**CT4**
DP1	0.023	0.058	0.076	0.139
DP2	0.022	0.058	0.08	0.172
DP3	0.023	0.064	0.076	0.133
DP4	0.024	0.072	0.082	0.102
Mean	**0.023**	**0.063**	**0.079**	**0.137**
SDV±	**0.0008**	**0.0066**	**0.003**	**0.0287**

Table-6 shows the data on volume flow rate of 90% packed erythrocytes of Diabetic blood. Erythrocytes were separated from plasma samples, four different radii i.e. 0.029cm, 0.040cm, 0.045cm and 0.055cm of capillaries were used to find out the volume flow rate of 90% packed erythrocytes. It is evident from the table given below that the volume flow rate increases as the radii of capillary tube increases.

Table - 6: Data on Volume flow rate of 90% packed erythrocytes of Diabetic Blood

Sample Code	Volume flow rate, Q (cm3 sec-1)			
	CT1	**CT2**	**CT3**	**CT4**
DE1	0.002	0.009	0.014	0.018
DE2	0.002	0.009	0.012	0.014
DE3	0.002	0.011	0.012	0.017
DE4	0.001	0.012	0.013	0.017
Mean	**0.002**	**0.010**	**0.013**	**0.017**
SDV±	**0.0005**	**0.0015**	**0.0010**	**0.0017**

FINDINGS AND DISCUSSION

In this study, it is observed that the coefficient of viscosity of Diabetic blood, plasma, and 90% packed erythrocytes increases nonlinearly with increase of radius of capillary tube (Tables 1, 2, 3). In a non-Newtonian fluids viscosity increases non linearly with the radius of a capillary tube. The volume flow rate of blood, plasma and 90%packed erythrocytes also increases with the increase of radius (Tables4, 5, 6). It is interesting to know that the coefficient of viscosity and volume flow rate both are proportionally increasing with the radius. In other words, it can be stated that the coefficient of viscosity increases as the flow rate increases.

Hence, it can be stated that the viscosity increases with the increase of radius of the tube (blood vessel).

It was observed that in very small diameter tubes the apparent viscosity of blood has a very low value. The viscosity increases with the increase in tube diameter. This phenomenon is referred to as the *Fahraeus-Lindqvist effect*, which says that the apparent viscosity of blood is a function of tube diameter. . As the blood flows through a tube, the blood cells tend to rotate and move towards the centre of a tube. Hence, a cell-free layer of thickness (δ) exists near the wall. In tubes with small diameter, the area of the cell-free zone is comparable to the central core. The net effect of the cell-free zone with a lower viscosity (viscosity of plasma alone) is to reduce the apparent viscosity of flow through the tube. As the tube diameter increases, the effect of the cell-free zone reduces and the viscosity coefficient approaches the asymptotic value.

Diabetes mellitus has high social and economic importance as the number of the diabetes patients continues to grow at an unprecedented rate throughout the world. Diabetes is the most frequent cause of legal blindness and renal failure and one of the major risk factors for cardiovascular diseases.

Hemorheological parameters in diabetes mellitus are often disturbed. These parameters include (but are not limited to) hematocrit, plasma proteins, erythrocyte aggregation, and erythrocyte deformability. The abnormalities associated with each of these parameters have been shown to markedly increase both plasma and whole blood viscosity (WBV).

In the present study the coefficient of viscosity in diabetic blood, plasma and 90%packed erythrocytes is high when compared to normal blood and its constituents .This is because of either low insulin level or insulin resistance at many body cells. Therefore hemorheological parameters in diabetes mellitus are often disturbed.

There is substantial evidence from many of the research studies that the elevated blood viscosity is a pathogenic factor for diabetic microangiopathy in DM altering the microcirculation leading to insufficient tissue perfusion. In this regard, the increased blood viscosity manifests all the adverse microscopic alterations occurring in diverse structures of circulating blood in diabetes. Increased blood viscosity could be particularly important in the etiology of diabetic retinopathy. Diabetic retinopathy can be described by dilated veins, micro aneurysms, haemorrhages, and vessel proliferation. The etiology of the diabetic microangiopathy may be the impairment of the microcirculation leading to a prolonged reduction in the supply of oxygen and nutrients to the capillary vessels. More specifically, the development of diabetic angiopathy has been related to abnormal hematocrit, plasma viscosity and erythrocyte aggregation, and decreased erythrocyte deformability. Since these parameters are the ones that determine the WBV, one may expect that the blood viscosity is also adversely altered in diabetic angiopathy.

Conclusions

The following conclusions can be drawn from the study

- The simple capillary viscometer serves as a potential tool in the absence of sophisticated instruments in diagnosing purpose.
- The advantage of viscometer developed in the laboratory is with respect to the quantity of blood sample. And it measures viscosity, surface tension and flow rate in an infinite length tube or vessel.
- The viscometer developed can be used with ease to study rheology of blood and its molecular (haemoglobin and serum) and cellular (packed erythrocytes and platelets) constituents.
- As viscosity of blood changes when blood flows through blood vessels of a large range of radii of vascular blood It warns medical discipline to handle vascular system with care.
- Viscosity is affected by various factors. It depends on the amount of plasma proteins, the number and the volume of corpuscles.
- Though there are many factors that individually affect the viscosity, but high blood viscosity invariably accompanies degenerative diseases. Because high blood viscosity always leads to a slow down of circulation and reduces oxygenation of tissues.
- The viscosity of blood depends on the rate of flow or shear rate. The changes in viscosity are a result of changes in the arrangement, orientation and stretching of the red blood cells

Abnormal blood viscosity plays an important role in diabetes. Therefore When treating the people with this disease much attention should be paid to regulate blood viscosity to avoid undesirable syndromes.

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