Viscosity of Normal Human Blood and Diabetic Blood – An Analytical Study

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***Abstract* - Blood is a vital fluid found in human beings and other animals. Blood viscosity is a basic biological parameter that affects blood flow both at large arteries and in microcirculation. Since blood is viscous by nature, the thickness and stickiness of an individual's blood is associated with many risk factors of health of a human being. In this study a simple technique is used to find out the viscosity of blood and its constituents at different flow rates by using normal capillary tubes, The tool is developed based on Poiseuille's theory to measure the coefficient of viscosity and volume flow rate at different radii. The data is presented and findings and conclusions are drawn from the data.**

***Index Terms* - Viscosity, Flow rate, Diabetes mellitus.**

1.INTRODUCTION

Human blood is a complex substance. There are three kinds of cells in the blood. (1) Red Blood Cells (RBC); (2) White Blood Cells (WBC); and (3) Platelets. Red blood cells, which carry oxygen from the lungs to the body tissues are major components found in the blood. White blood cells have major role in disease prevention and immunity; and platelets are key elements in the blood clotting process. These blood elements are suspended in blood plasma, which is a yellowish liquid that comprises about 55% of human blood. The different kinds of blood cells have different "life spans." Red blood cells last about 120 days in the blood stream; platelets about 10 days; and the various kinds of white blood cells can last from days to years.

Blood viscosity is a basic biological parameter that affects blood flow both at large arteries and in microcirculation. Since blood is viscous by nature, the thickness and stickiness of an individual's blood is associated with many risk factors of health of a human being. Under normal physiological conditions viscosity of blood varies because of many factors like gender, geography and heredity and 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, erythrocytes with high shear rates is a major determination of viscosity of blood.

2.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-ended capillary viscometer is used and a theory developed on the Poiseuille's theory for the 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 viscometry technique, which is employed in the study, is used to measure both viscosity and volume flow rate. The blood samples were collected from both normal and diabetic patients with Ethylene Diamine Tera Acetic (EDTA) in the powder form. Plasma was separated from blood by centrifuging. 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, Haematocrit of sample is maintained to be constant.

3.RESULT AND DISCUSSION

Table 1 indicates the data on coefficient of viscosity of water. Four 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 of water. Five samples of water were taken for different capillary tubes and found the viscosity. It is found that there is no change in the coefficient of viscosity of water with different radii of capillary tubes.

Table 1: Data on coefficient of Viscosity of Water
CT=Capillary Tube
CT1= 0.029cm; CT2= 0.040cm; CT3= 0.045cm; CT5= 0.055cm

Sample Code	Viscosity, η (poise)			
	CT1	CT2	CT3	CT4
W1	0.012	0.012	0.012	0.012
W2	0.012	0.012	0.012	0.012
W3	0.013	0.013	0.013	0.013
W4	0.013	0.013	0.013	0.013
W5	0.012	0.012	0.012	0.012
	Mean:0.012	Mean:0.012	Mean:0.012	Mean:0.012
	S.D= ±0.0005	S.D= ± 0.0005	S.D= ±0.0005	S.D= ± 0.0005

Table 2 shows the data on coefficient of viscosity of human 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 as the radius of the capillary tube increases, the coefficient of viscosity also increases.

Table 2: Data on coefficient of Viscosity of Human Blood

Sample Code	Viscosity, η (poise)			
	CT1	CT2	CT3	CT4
HB1	0.02427	0.02663	0.02889	0.03927
HB2	0.02126	0.02399	0.03393	0.0434
HB3	0.02184	0.02308	0.03009	0.04825
HB4	0.02663	0.03055	0.03505	0.04849
HB5	0.02951	0.03062	0.03551	0.05101
HB6	0.02569	0.039	0.03924	0.04541
HB7	0.02569	0.02926	0.03414	0.04732
HB8	0.02539	0.02968	0.03414	0.04014
HB9	0.03765	0.03405	0.04045	0.04243
HB10	0.02951	0.03582	0.03984	0.04043
HB11	0.03368	0.03516	0.03804	0.04227
HB12	0.02968	0.03057	0.0364	0.03889
HB13	0.02473	0.03595	0.03677	0.04611
HB14	0.02299	0.02971	0.03553	0.04237
HB15	0.02698	0.02873	0.03286	0.04732
HB16	0.02299	0.02846	0.03553	0.0479
mean	0.027	0.031	0.035	0.044
S.D=±	0.0044	0.0044	0.0032	0.0038

Table 3 shows the data on volume flow rate of water. For five samples of water four different radii of i.e.0.029cm, 0.040cm, 0.045cm and 0.055cm of capillary tubes were taken to find out the volume flow rate. It is observed from the given table that the flow is continuous when the length is infinite.

Table 3: Data on Volume flow rate of water

Sample Code	Volume flow rate, Q (cm3 sec-1)			
	CT1	CT2	CT3	CT4
W1	0.035	0.06757	0.08552	0.12775
W2	0.033	0.06406	0.08107	0.12111
W3	0.031	0.06029	0.076302	0.113982
W4	0.035	0.066819	0.084568	0.126335
W5	0.032	0.061041	0.077255	0.115406
Mean	0.034	0.064	0.081	0.121
S.D= ±	0.0017	0.0033	0.0042	0.0062

Table 4. gives the data on volume flow rate of human 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 Human Blood

Sample Code	Volume flow rate, Q (cm3 sec-1)			
	CT1	CT2	CT3	CT4
HB1	0.01188	0.03918	0.05786	0.06498
HB2	0.01188	0.03173	0.04955	0.06082
HB3	0.0132	0.04521	0.0561	0.07844
HB4	0.01082	0.03416	0.04768	0.07693
HB5	0.01293	0.0371	0.05086	0.07313
HB6	0.01199	0.04069	0.04924	0.08216
HB7	0.01122	0.03567	0.04896	0.07883
HB8	0.01135	0.035	0.04896	0.06319
HB9	0.01165	0.03064	0.04133	0.06174
HB10	0.00977	0.0305	0.04433	0.06174
HB11	0.01101	0.0331	0.04289	0.0617
HB12	0.01147	0.03516	0.04942	0.07313
HB13	0.01103	0.0331	0.04673	0.06648
HB14	0.01154	0.0376	0.04705	0.07123
HB15	0.01158	0.0301	0.04005	0.07218
HB16	0.01154	0.03667	0.04705	0.07788
Mean	0.012	0.035	0.048	0.070
S.D= ±	0.0008	0.0041	0.0047	0.0073

Table 5: Data on coefficient of viscosity of Diseased 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

Table 6: Data on Volume flow rate of Diseased 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

Fig.1. A plot between Volume flow rate on x-axis coefficient of viscosity on y-axis of water.

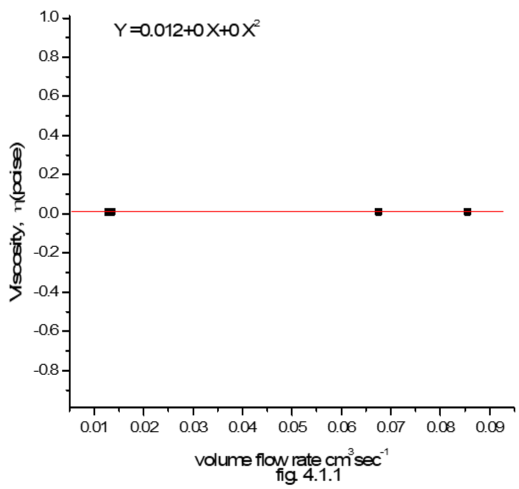


Fig.2. A plot between volume flow rate on x-axis and coefficient of viscosity on y-axis for human blood.

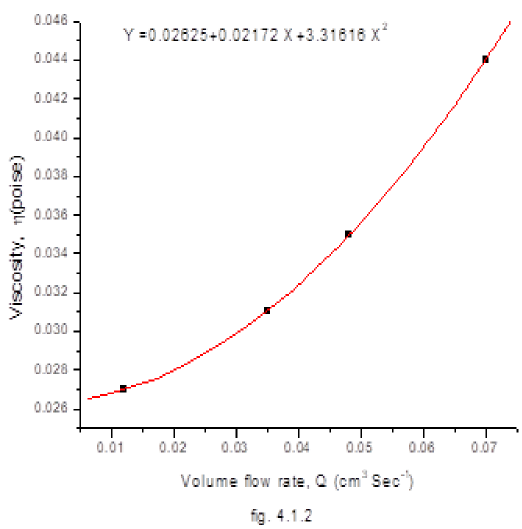


Fig.3 : A plot between Radius-R(Cm) on X-Axis and coefficient of viscosity on y-axis of water.

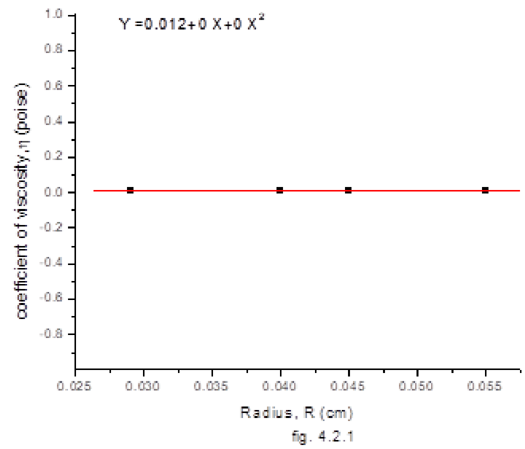
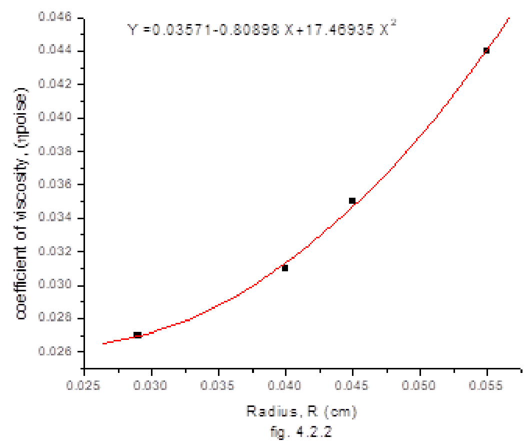


Fig. 4: A plot between Radius on x-axis and Coefficient of viscosity on y-axis of human blood.



TFig.5: A plot between Radius on X-axis and Volume flow rate on Y-axis for water.

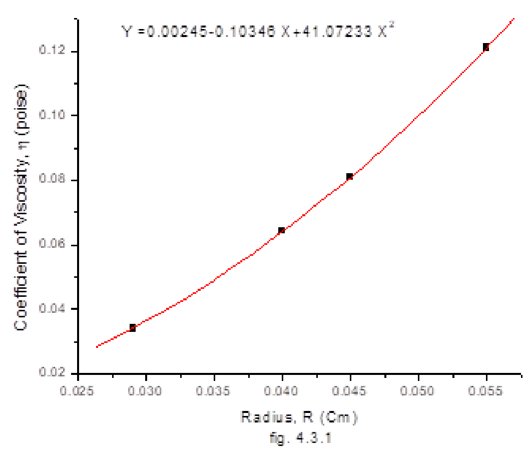


Fig.6: A plot between Radius on X-axis and Volume flow rate on Y-axis for human blood.

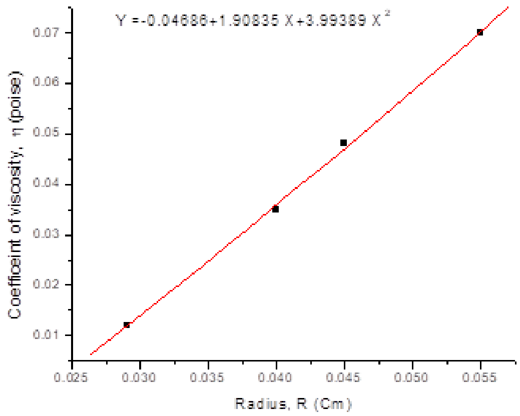


fig. 4.3.2

In the present study, it is observed that the coefficient of viscosity of blood increases nonlinearly with increase of radius of capillary tube (Tables 2). But in the case of water, the coefficient of viscosity remains constant (Table1). As it is known, in Newtonian fluids the viscosity is independent of resistance and the stress, strain relation is linear (Fig.1), whereas in a non-Newtonian fluids viscosity increases non linearly with the radius of a capillary tube (Fig.2). The volume flow rate of blood also increases with the increase of radius (Table 4). 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.

Similarly, the coefficient of viscosity in diabetic blood is high when compared to normal blood. This is because of either low insulin level or insulin resistance at many body cells. Therefore, hemorheological parameters in diabetes mellitus are often disturbed.

4.CONCLUSION

Blood viscosity is a basic biological parameter that affects blood flow both at large arteries and in microcirculation. 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. In diabetes mellitus, there is sufficient evidence that the elevated blood viscosity is a pathogenetic factor of diabetic microangiopathy, altering microcirculation and leading to insufficient tissue nutrition. 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.

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