

# Effect of MRI on Blood Viscosity

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**Abstract: Background and objectives:** Blood viscosity is a measure of the “thickness” of the blood. Blood viscosity in healthy persons is almost constant, but it can be affected by many factors. It strongly depends on hematocrit. A second important factor that influences blood viscosity is body temperature; there is an inverse relationship between temperature and viscosity. During Magnetic Resonance Imaging, the patient is exposed to strong magnetic field and the Radiofrequency range, may led to change in blood viscosity .The present study was performed to define the relationship between blood viscosity and exposure to magnetic field. **Methods:** The effect of Magnetic Resonance Imaging (MRI) on blood viscosity of fifty patients subjected to MRI was measured by U-tube viscometers before and after exposure to MRI. **Results:** There was specified effect of Magnetic Resonance Image on blood viscosity. The frequencies generally used in a Magnetic Resonance Image scanner are in the range at which high absorption occurs in the whole body, which causes body temperature rises as a result of the Radiofrequency energy absorption. Therefore the blood viscosity decrease, there is an inverse relationship between temperature and viscosity. **Conclusion:** Randomly selected exposed to Magnetic field strength 1.5 T demonstrated specify changing in blood viscosity.

**Keywords:** MRI, Blood Viscosity, Biophysical properties, Temperature.

**Abbreviations:** t: the time for the bubble to drop a specific distance (s), k: the calibration constant for the tube, BV: blood kinematic viscosity.

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## 1. Introduction

Viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. Abnormalities in blood viscosity have been implicated in a number of cardiovascular diseases. [1–2] Given the direct role of whole blood viscosity (WBV) in determining vascular resistance, recognized by Poiseuille, [3] there is interest in possible relations between viscosity and hypertension. [4–5] A study performed in normotensive subjects [6] demonstrated an independent association of WBV with diastolic or mean blood pressure, but not with systolic pressure, giving support to further research to investigate possible relations of WBV with hypertension and other cardiovascular risk factors. However, most mechanisms remain unclear. [7] unfortunately, direct determination of in vitro WBV is technically demanding and difficult to apply in epidemiological studies. We have previously shown that up to 83% of variability of WBV could be explained by microhematocrit and total plasma protein concentration (as a surrogate of plasma viscosity) over a range of shear rates from 0.1 to 208 seconds [8]. A common method for determining the viscosity is “the capillary tube viscometer “. It depends on the measurement of the fluid’s free flow time due to gravitational force through a vertical tube that has a constant radius, length, and volume. The relative viscosity value for serum is 1.4 to 1.8, for the plasma relative viscosity is 1.7 to 2.2, and the whole blood viscosity is between 2.5 and the blood is non-Newtonian, meaning that viscosity is not independent of flow at all flow velocities [9]. In fact, during conditions such as circulatory shock where microcirculatory flow in tissues is reduced because of decreased arterial pressure, low flow states can lead to several-fold increases in viscosity. Low flow states permit increased molecular interactions to occur between red cells and between plasma proteins and red cells. This can cause red cells to stick together and form chains of several cells (Rouleau formation) within the microcirculation, which increases the blood viscosity<sup>[10, 11]</sup>. The magnetic field polarizes the red blood cells causing them to link together in short chains, streamlining the movement of blood. Because these chains are larger than single blood cell, they flow down the center, reducing the friction against the walls of the blood vessels . The combined effects reduce the blood viscosity, helping it to flow more freely.<sup>[12]</sup>

Another important factor that influences blood viscosity is temperature. When blood gets cold, it get "thicker" and flows more slowly. Therefore, there is an inverse relationship between temperature and viscosity. Viscosity increases about 2% for each degree centigrade decrease in temperature<sup>[13, 14]</sup>. The aim of this study: was to define the relationship between blood viscosity and exposure to magnetic field..

## 2. Methods

In this study randomly selected fifty Patients who were referred to department of MRI in Rizqari teaching hospital, were exposed to 1.5 T magnetic fields. Ranging age from 23 to 55 years, 22 males (44%) and 28 (56%) female. Their blood viscosity was measured before and after MRI using capillary tube viscometer.

**A.** Preparation of the blood samples : after at least 8 hours fasting , (5 ml ) of venous blood sample were taken using plastic syringes without any coagulant from the patient immediately before and after exposure to 1.5 T magnetic field ( 1.5 T Siemens symphony Erlangen).

**B.** Measurement of viscosity of blood: the flow times of samples were measured by a capillary tube viscometer (Fig. 1) that has a reservoir with a volume of 2mL at the upper part. It was filled with sample in the vertical position until the upper mark of the reservoir and the free flow time of the liquid to the lower mark of the reservoir was measured in seconds (s) and used as the data. During the measurement of viscosity , each measurement was repeated and controlled three times , and the physical conditions (temperature and humidity ) of the laboratory were kept constant and the blood viscosity can be measured [6] .

$$v = ( t \times k ) \times 10^{-6} \text{ (m}^2\text{/s)} =$$

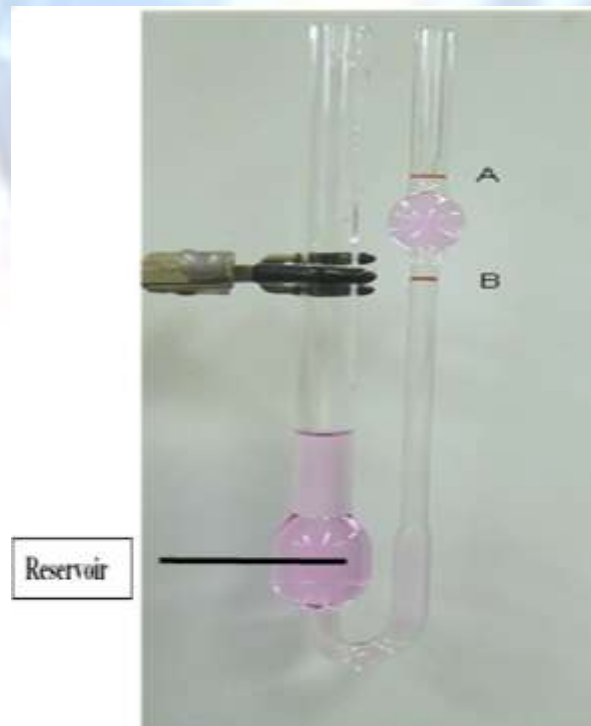
The blood kinematic viscosity (BV) = (the calibration constant for the tube) X (the time for the bubble to drop a specific distance (s) )

$$BV = ( T \times k ) \times 10^{-6} \text{ (m}^2\text{/s)} \text{ [7]}$$

K= 0.0285 X 10<sup>-6</sup> (m<sup>2</sup>/s<sup>2</sup>) = is the calibration constant for the tube

(K was determined by using comparative measurements with reference viscometer) [7]

T= is the time for the bubble to drop a specific distance (s)



**Figure 1. U-tube viscometers [15].**

### 3. Results

This study show a high significant decrease ( $P < 0.001$ ) in blood viscosity during MRI (Table 1), and the reduction in blood viscosity before and after exposure to MRI is about 6.57%. Correlation is significant between the age and the blood kinematic viscosity (table 2). And correlation is significant if the blood kinematic viscosity has been compared before and after MRI exposure (table 2). he influence of the age on blood viscosity was noticeable in which the blood viscosity was higher in older age (Fig. 2) , even though we exposed the patients to MRI (Fig. 3).

After more than one hour from exposure to MRI, when the magnetic field was taken away, the blood's original viscosity state slowly returned. The Polynomial statistical Model “at order =4” has been applied in which R2 value is slightly increased when compared with the Linear statistical Model (Fig. 4, 5). Many statistical Models have been used in which different R2 value is obtained from each statistical model, and the largest (highest) R2 value was found with Polynomial Model (table 3) .

Table 1. There is a high significant decrease ( $P < 0.001$ ) of mean blood kinematic viscosity post MRI, using t- test.

Paired Samples Statistics						
	Mean	N	Std. Deviation	t-test value	d.f.	P-Value
the blood viscosity Before	3.6182	50	0.401	14.096	49	<0.001
the blood viscosity After	3.3804	50	0.345			

Table 2. Correlations matrix between (Age, the kinematic viscosity before, and the kinematic viscosity after)

	the kinematic viscosity Before	the kinematic viscosity After
Age	0.692**	0.659**
the kinematic viscosity Before		0.960**

\*\* Correlation is significant at the 0.01 level. N=50

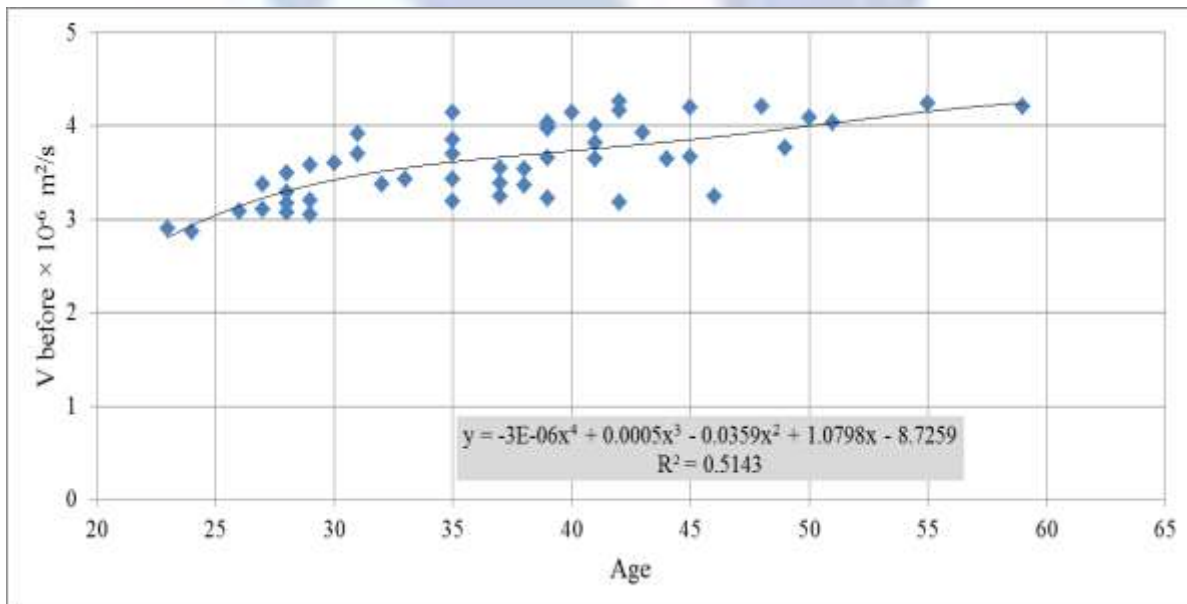


Figure 2. The relationship between the blood kinematic viscosity before exposure to MRI and age for fifty patients ranging from 23 to 55 years, with constant temperature (25 C<sup>o</sup>).

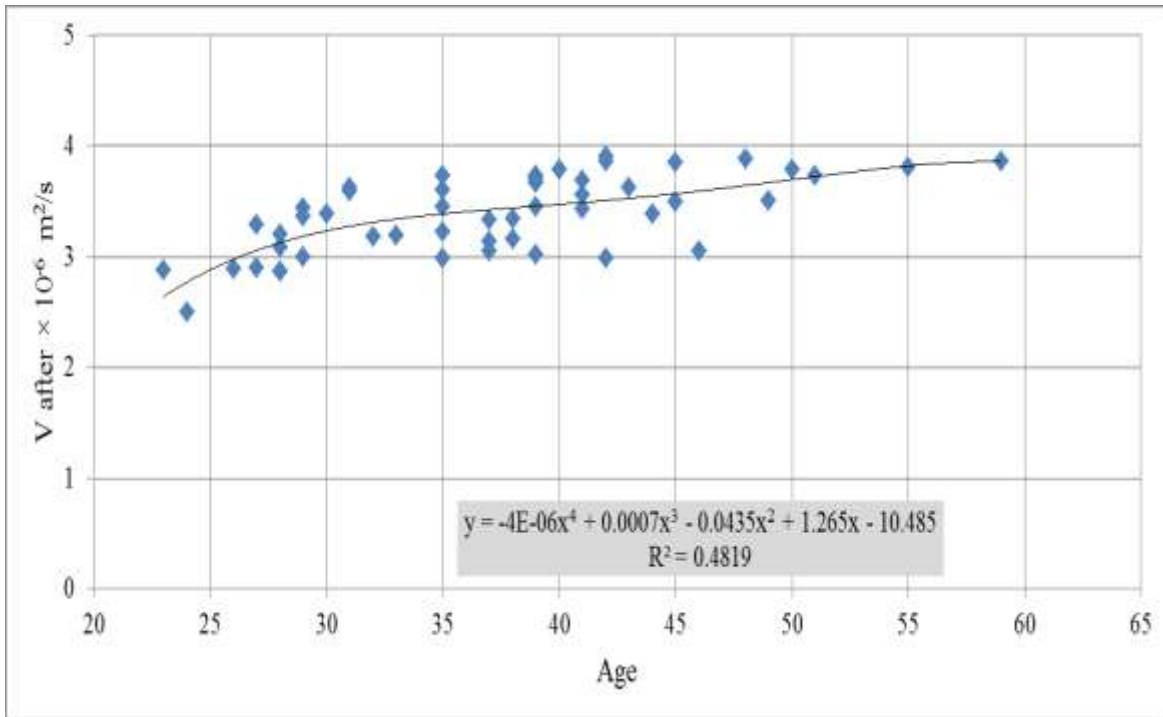


Figure 3. The relationship between the blood kinematic viscosity after exposure to MRI and age for fifty patients ranging from 23 to 55 years, with constant temperature (25 C o).

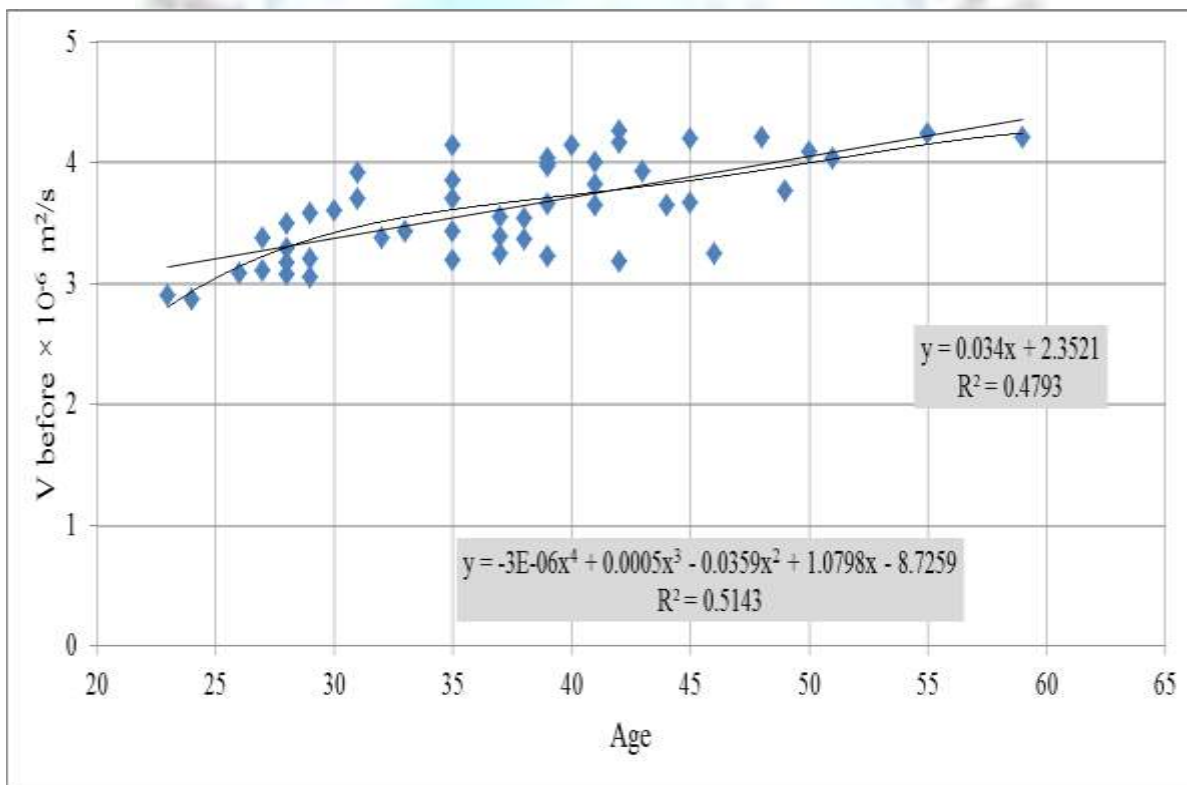


Figure 4. compare between two statistical models ( linear model  $R^2= 0.4793$  and Polynomial model at order 4,  $R^2= 0.5143$  ) to The relationship between the blood kinematic viscosity before exposure to MRI and age for fifty patients ranging from 23 to 55 years, with constant temperature (25

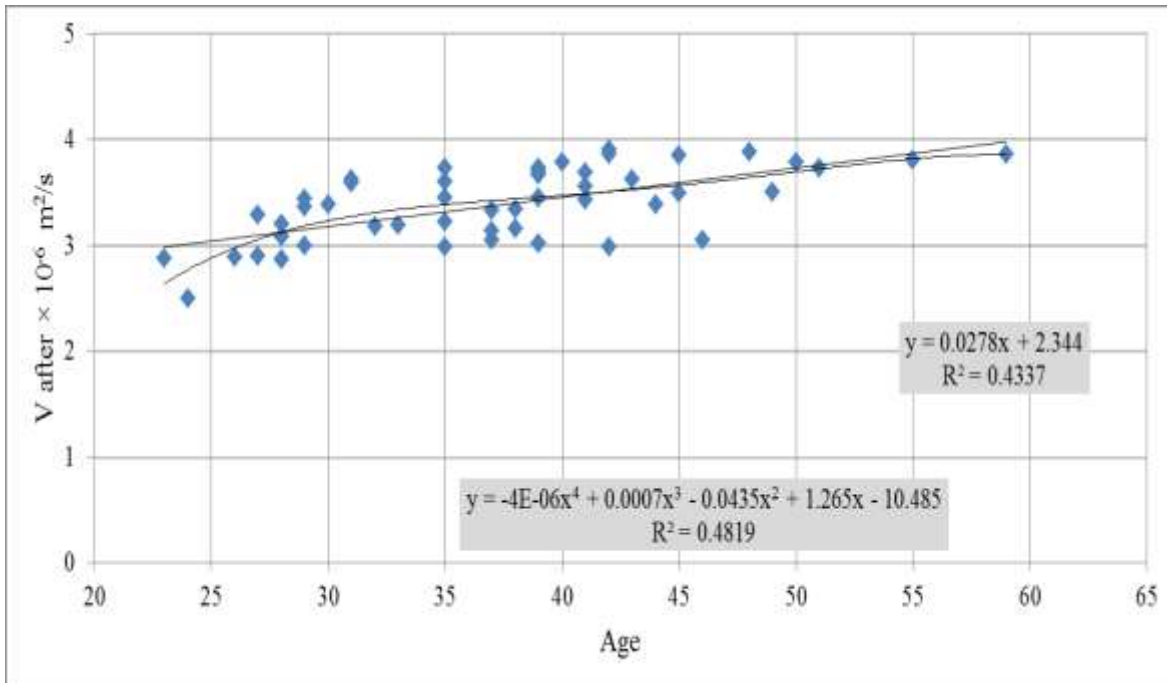


Figure 5. Compare between two statistical models ( linear model R2= 0.4337 and Polynomial model at order 4, R2= 0.4819 ) to The relationship between the blood kinematic viscosity after exposure to MRI and age for fifty patients ranging from 23 to 55 years, with constant temperature (25C°)

Table 3. There are many statistical models with different R<sup>2</sup> value for the blood kinematic viscosity (before and after MRI exposure) with age.

Name of Statistical Model	Value of R <sup>2</sup> (Before MRI exposure)	Value of R <sup>2</sup> (After MRI exposure)
Polynomial Model at order =4	0.5143	0.4819
Linear Model	0.4793	0.4337
Exponential Model	0.4779	0.4269
Logarithmic Model	0.4988	0.4819
Power Model	0.5028	0.4543

#### 4. Discussion

In this study, there are several physical parameters of interaction between tissues and strong magnetic fields (B+) and Electromagnetic radiation ( EM) that could lead to effect on the blood viscosity. These parameters Such as: the Temperature has great effect on the blood viscosity including whole blood components and plasma. Blood viscosity increases as body's temperature decreases that means viscosity is strongly dependent on body's temperature. A decrease of 1°C in temperature yields a 2% increase in viscosity. Also the viscosity of blood depends on velocity of the blood (The viscosity is dependent on the flow rate. At very low flow rates the cell and molecular interactions increase to a pathological state enabling red blood cell adhesion, therefore causes to increase the viscosity). More exactly formulated, when velocity increases viscosity decreases[17, 18]. At higher velocity the disc-shaped Red Blood cells (RBC's, erythrocytes) orient in the direction of the flow and viscosity is lower.

Poiseuille's equation gives factors that change the resistance of blood vessels<sup>3</sup>

$$R = (8\eta l) / (\pi r^4) \dots\dots\dots (1)$$

R = resistance

η = viscosity of blood

l = length of blood vessel (m)

r<sup>4</sup> = radius of the blood vessel to the fourth power

There are three primary factors that determine the resistance to blood flow within a single vessel: Vessel diameter (or radius), vessel length and viscosity of the blood. The most important quantitatively and physiologically is vessel diameter, and very small changes in vessel diameter lead to large changes in resistance. During MRI scanner there is a powerful radio transmitter to generate the electromagnetic field which excites the spins. If the body absorbs the energy, heating occurs. And According to the above equation (1):

Vessel resistance (R) is directly proportional to the viscosity ( $\eta$ ) of the blood, and inversely proportional to the radius to the fourth power ( $r^4$ ). Therefore the volume flow rate is inversely proportional to viscosity.

For this reason, the transmitter rate at which energy is absorbed by the body has to be limited, this agrees with Pacini et al.<sup>[19]</sup>. Therefore viscosity of blood decrease as the temperature increases, this agree with Kesmarky G.<sup>[20]</sup>.

The decrease in blood viscosity is due to the effect of the strong magnetic field and Radio Frequency (RF) on body which contains the blood, this agree with<sup>[22]</sup>, and all their statistical values (using t-test) are significant.

### Conclusion

This study confirms that is MRI is therapeutic agent along with its diagnostic properties through its relation with blood viscosity which is a major factor in many diseases such as heart disease. When blood viscosity increases, it damages blood vessels and increases the risk of heart attacks. But blood viscosity can be reduced with magnetic fields, therefore exposure to MRI can have a temporary effect on blood viscosity and a temporary effect led to improving blood flow and thereby reducing risk of many diseases. After the exposure, in the absence of magnetic field, the blood viscosity returns to the original value. So this effect will have any future clinical applications remains to be seen.

### Recommendations

1. In this research we used the magnetic field strength at 1.5 T; we recommend future studies with higher magnetic field strength.
2. We also recommend further experiments on animals' model with increasing exposure time to MRI.

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