MAGNETIC FIELDS AND BLOOD FLOW

EFFECT OF THE MAGNETIC FIELD ON THE VISCOSITY AND REYNOLDS NUMBER OF BLOOD IN THE ABDOMINAL AORTA

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ABSTRACT

Blood viscosity plays a crucial role in determining blood flow dynamics and has significant implications for cardiovascular health. Understanding how external factors, such as magnetic fields, influence blood viscosity and flow characteristics can offer new therapeutic insights. This study investigates the effect of hematocrit levels on blood viscosity and the Reynolds number in the abdominal aorta and evaluates the potential impact of applying a magnetic field on these parameters. Graphical analysis highlights that magnetic field application can reduce blood viscosity, thereby increasing the Reynolds number and potentially improving blood flow.

Keywords : *Reynolds number, blood viscosity, magnetic field, hematocrit, blood flow*

INTRODUCTION

Blood viscosity is a critical parameter in cardiovascular physiology, as it influences blood flow resistance and overall hemodynamics. High viscosity is associated with increased vascular resistance, higher blood pressure, and a greater risk of clot formation, all of which can contribute to cardiovascular diseases ***(5).*** Blood viscosity depends on several factors, including hematocrit, temperature, and flow velocity. Hematocrit, defined as the proportion of red blood cells in blood, is directly proportional to viscosity, with higher hematocrit levels leading to increased viscosity ***(1).***

The Reynolds number is a dimensionless parameter used to characterize fluid flow patterns, including whether the flow is laminar, turbulent, or transient. It is influenced by blood viscosity, average flow velocity, and arterial diameter. In the abdominal aorta, achieving a Reynolds number above 2000 is desirable to maintain turbulent flow and avoid stagnation, which could lead to clot formation ***(7).***

Applying a magnetic field to blood flow has been shown to decrease viscosity by altering the orientation and aggregation of red blood cells ***(8).*** This study aims to investigate how magnetic fields influence the Reynolds number and blood flow dynamics, providing potential therapeutic insights.

Objectives

The primary objectives of this study are:

1. Investigate the effect of varying magnetic field strengths and orientations on blood viscosity.
2. Determine the impact of magnetic field exposure on the Reynolds number of blood flow.
3. Explore the potential mechanisms underlying these observed effects.

This research has significant implications for understanding blood flow dynamics and developing novel therapeutic approaches for cardiovascular diseases.

Nomenclature

- **r (m)**: Radius of the artery
- **Re**: Reynolds number
- **Ht (%)**: Hematocrit
- **η (Pa·s)**: Viscosity of blood
- **B (Tesla)**: Magnetic field
- **V (m/s)**: Average blood velocity

METHODOLOGY

The study analyzed Reynolds numbers for varying hematocrit levels in different blood vessels, including the aorta, middle arteries, arterioles, capillaries, and veins. The following average blood velocities and radii were used for these analyses (Table 1).

Blood Vessel	Average Velocity (cm/s)	Radius (cm)
Aorta	30 - 40	0.9 - 1.5
Middle Arteries	15 - 30	0.1 - 0.45
Arterioles	1 - 3	0.002 - 0.0055
Capillaries	0.03 - 0.7	0.00025 - 0.0005
Veins	10 - 20	0.00225 - 0.45

Equations

The correlation obtained for the calculation of blood viscosity as a function of hematocrit is:

$$\mu(Ht) = 1{,}6532 \exp(2{,}9963\, Ht) \qquad (1)$$

For the calculation of the Reynolds number, the following relation is used:

$$Re = \frac{2\rho_{blood} v_m r}{\mu(Ht)} \qquad (2)$$

In the case of the abdomial aorta the radius is equal to 0.009 m and $v_m(m/s)=0{,}35$

The relationship between hematocrit and blood viscosity was modeled using established correlations ***(1).*** To account for the impact of magnetic fields, a reduction in viscosity by 20% was assumed based on the findings of Tao and Huang (2011).

RESULTS

The results demonstrate the critical relationship between hematocrit levels, blood viscosity, and the Reynolds number in the abdominal aorta. Figure 1 illustrates that as the hematocrit rate increases, the Reynolds number progressively falls below 2000. This decrease is concerning since maintaining Reynolds numbers slightly above 2000 is essential to promote flow resistance and create beneficial shear forces within the aorta. A low Reynolds number may lead to blood stasis, increasing the risk of clot formation and vascular obstruction.

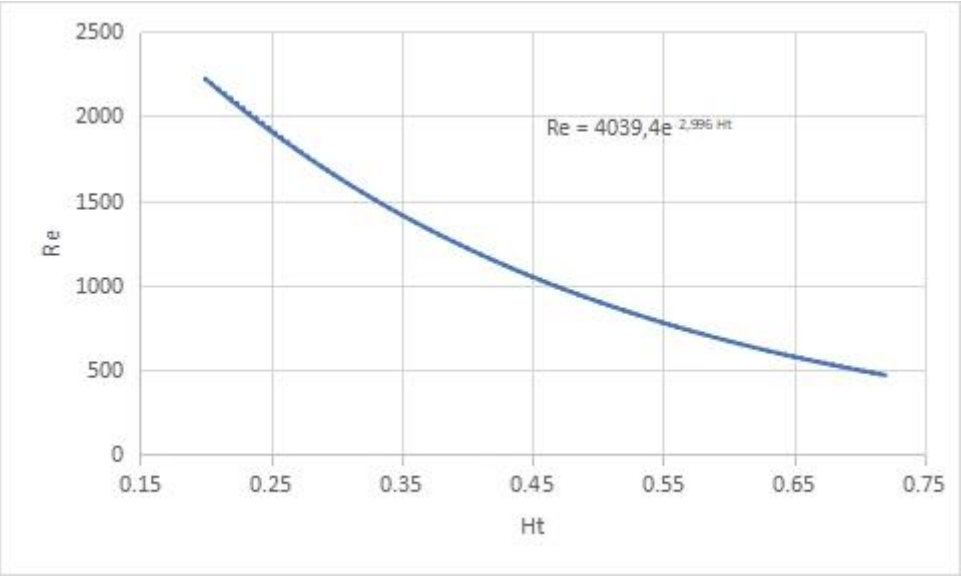

***Figure 1** : Evolution of the Reynolds number as a function of hematocrit rate*

It would be interesting to apply a magnetic field to decrease the viscosity and thus increase the Reynolds number in this region and bring it back to the turbulent state because if the Re is too low it could lead to blood stasis and promote the formation of clots and the risk of vascular obstruction.

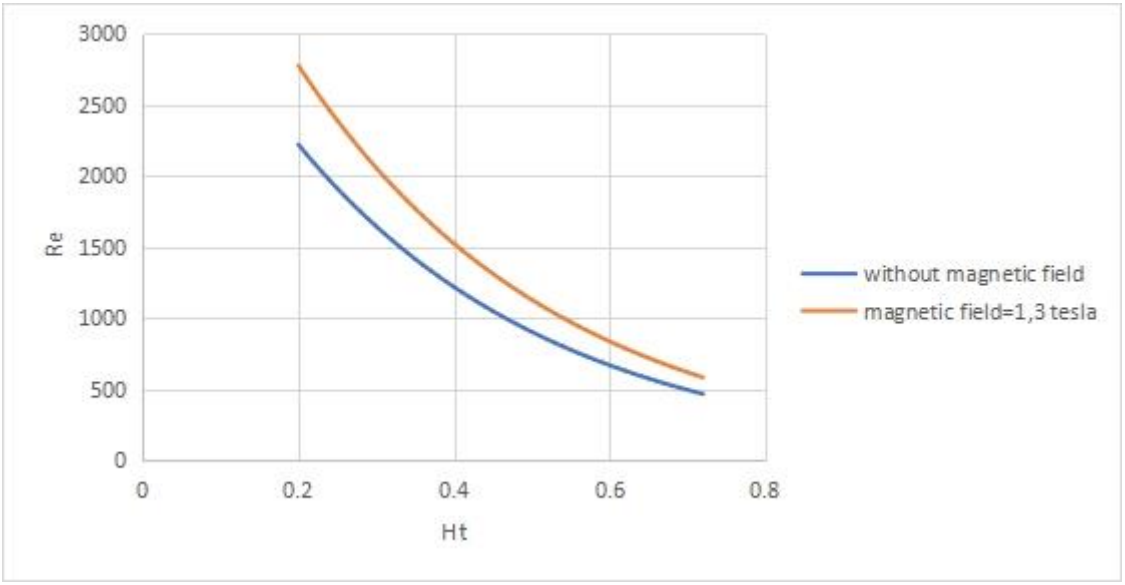

***Figure 2** : Effect of magnetic field in the Reynolds number as a function of hematocrit rate*

Figure 2 further highlights the potential of magnetic field intervention. The application of a 1.3 Tesla magnetic field results in a 20% reduction in blood viscosity, leading to an increase in the Reynolds number above 2000 across a larger region. These findings suggest that magnetic field therapy could restore turbulent flow and improve hemodynamic stability in conditions characterized by elevated hematocrit levels.

Interpretation And Discussion

The analysis confirms that increasing hematocrit levels lead to higher blood viscosity and a corresponding decrease in the Reynolds number. This trend is particularly concerning in the abdominal aorta, where low Reynolds numbers can promote blood stasis and increase the risk of clot formation.

The application of a magnetic field proved to be a promising intervention. By decreasing blood viscosity by 20-30%, the Reynolds number increased, promoting more favorable hemodynamic conditions. These findings suggest that magnetic field application could serve as a therapeutic tool to regulate blood flow, particularly in cases where elevated hematocrit levels pose a risk.

The results align with previous studies that have highlighted the potential of magnetic fields to influence blood viscosity and flow dynamics ***(3; 4; 5 and 7).*** Additional evidence supports the influence of magnetic fields on blood flow properties through the modulation of red blood cell aggregation and deformation ***(2 and 6).***

Further research is recommended to optimize magnetic field strength and orientation for clinical applications.

CONCLUSION

This study underscores the importance of blood viscosity and Reynolds number in maintaining optimal blood flow dynamics. By investigating the impact of hematocrit levels and magnetic field application, we demonstrated that magnetic fields could serve as a viable strategy to

improve blood flow and reduce the risk of clot formation. These findings have significant implications for the development of novel therapeutic approaches for cardiovascular diseases.

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