ID: LB172
Computational Model of Nuclear Magnetic Resonance (NMR) Bloch Flow Equation for Hemorheology

Michael Dada, Federal University of Technology, Minna, Nigeria, dadamichael@futminna.edu.ng

Category: Cardiology

Abstract Body : Introduction Hemorheology is the study of flow properties of blood and the components (plasma, red blood cells, white blood cells and platelets). Blood viscosity is determined by plasma viscosity, hematocrit and mechanical behaviour of red blood cells leading to the mechanics of these cells being the major determinant of flow properties of blood [1]. However, blood does not behave like tissue on MR scan due to physiologic feature of maximizing oxygen transport. There is a close correlation between the rheologic and MR properties of protein molecules. The high concentration of intracellular hemoglobin is actually at a physiologic limit. Despite this high concentration, the lack of organelles and other macromolecular features of nucleated cells ensure blood's low viscosity and apparent magnetization transfer rates (RAMT) which was achieved with the use of magnetization transfer studies [2]. This demonstrates the importance of developing a model for mapping the viscosity-dependent NMR signal for hemorheology. Methods Above the normal intracellular hemoglobin concentration, viscosity rises very steeply and thus interferes with blood circulation. In fact, increased viscosity has been found to be lead to decreased mobility of the hemoglobin molecule; manifesting in increased RAMT and T2 relaxation rate [2]. Hence, we shall develop a viscosity-dependent transverse magnetization due to blood spin dynamics based on the time-independent Bloch NMR flow equation [3]. If the spin dynamics is within a rotating frame, then resonance condition exists at Larmor frequency [3]. From the NMR Bloch flow equations (My is the transverse magnetization), equation of motion of the spins moving with a variable velocity v(x) is given by eqn (1). If the RF field B1(x) is applied such that My is sampled at maximum magnitude, M0 ≈ 0; since rheology is concerned with fluids with variable viscosity and if we then take v(x) as the mean flow velocity with x being the characteristic length of the blood vessel, assuming eqn (2) is true and given that δ = pulse time, Re = Reynolds number, μ = dynamic viscosity, β = dimensionless parameter while ρ = density of blood. Eqn (2) becomes eqn (3) whose solution is given in eqn (4) (where β = RAMTT2 and C1 is a constant). Results We have applied the result obtained in equation (5) to unclotted blood samples with intact red blood cells. The NMR properties of these samples as related to blood rheology have been measured in earlier study [2] and are presented in Table 1. We developed a Mathematica (version 9) computer code for mapping the transverse magnetization of the components and the associated flow velocity. Using experimental ranges of viscosity in human blood flow [4] and Table 1, we have the maps in Figure 1 for low Reynolds number (Re = 10). Discussion and Conclusion We have developed a model in which My is obtained in terms of blood rheological parameters. With this model, different flow regimes could be obtained for various levels of viscosity and hence, different shear forces. This is demonstrated in the unique patterns shown in Figure 1. In conclusion, ease with which images of rheological flow could be obtained is the most interesting part of this study. The influence of turbulent flows can be easily obtained by simply changing the values of the Reynolds number in the computer program.

References: [1] Baskurt OK, Meiselman HJ. Blood rheology and hemodynamics. InSeminars in thrombosis and hemostasis 2003 Oct 1 (Vol. 29, No. 5, pp. 435-450). New York: Stratton Intercontinental Medical Book Corporation, c1974. [2] Gomori JM, Grossman RI, Asakura T, Schnall MD, Atlas S, Holland G, Mittl RL. An in vitro study of magnetization transfer and relaxation rates of hematoma. American journal of neuroradiology. 1993; 14(4):871-80. [3] Gupta A, Stait-Gardner T, Ghadirian B, Price WS, Dada OM, Awojoyogbe OB. Theory, Dynamics and Applications of MR Imaging-I. Science PG, 2014; New York, USA. [4] Rosenson RS, McCormick A, Uretz EF. Distribution of blood viscosity values and biochemical correlates in healthy adults. Clinical Chemistry. 1996; 42(8):1189-95.

Image/Figure:

https://www.xcdsystem.com/wmis/abstract/File5042/LB172_ImageFigure_0702023810.jpg

DraftModeStatus: 0

First Name: Michael

Last Name: Dada

Email: dadamichael@futminna.edu.ng

Organization: Federal University of Technology, Minna, Nigeria

Country: Nigeria