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Comprehensive Study of Blood Flow Dynamics in Arteries and Strategies for COVID-19 Prevention

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Abstract: ***The COVID-19 pandemic has underscored the need for comprehensive healthcare approaches that encompass not only the prevention of viral spread but also the management of associated health complications. This research focuses on the mathematical analysis of arterial blood flow and its implications for developing effective COVID-19 prevention strategies. This study has explored the critical role of platelets in worsening lung inflammation and forming blood clots in COVID-19 patients, leading to severe conditions like heart attacks and strokes. Platelets, beyond their clotting function, interact with the virus and trigger inflammatory responses. The study also examined how factors like hemoglobin, red blood cells, and platelet counts influence blood viscosity, which affects circulation. Plasma viscosity remains unaffected by these cellular components. To address high blood viscosity and improve blood flow, the study evaluates the combined use of Hydroxychloroquine and Doxycycline. Hydroxychloroquine lowers blood sugar and reduces blood viscosity, while Doxycycline treats respiratory infections and inflammation. Numerical analysis shows that these medications can enhance blood flow and reduce complications, offering potential benefits for managing inflammation, lung infections, and cardiovascular issues in COVID-19 patients. By understanding the dynamics of blood flow through the arteries, especially in populations vulnerable to severe COVID-19 outcomes, we can enhance public health policies and individual health practices. This paper integrates mathematical modeling, clinical insights, and preventive healthcare strategies to provide a holistic approach to managing the risks associated with COVID-19.***

Keywords: Stenosis, Blood Flow Dynamics, Viscosity, Resistance, Hydroxychloroquine, Doxycycline, COVID-19, Cardiovascular Disorders, Inflammation, Lung Infections

1. Introduction

COVID-19, caused by the SARS-CoV-2 virus, has led to significant global health challenges. The virus predominantly affects the respiratory system but can also have severe impacts on cardiovascular health, particularly in individuals with pre-existing conditions [4, 27, 31, 42]. Understanding the relationship between arterial blood flow and COVID-19 is crucial for developing targeted prevention and treatment strategies [8, 13, 29, 30]. The rapid emergence and global spread of the respiratory syndrome coronavirus (COVID-19) have placed unprecedented demands on healthcare systems worldwide. This crisis has significantly disrupted medical management globally, affecting regions such as Asia, Europe, and the United Kingdom [10, 44, 63, 74]. The full extent of this disruption remains unclear. In the UK, the first COVID-19 case in Scotland was reported on March 1, 2020 [33, 56]. The following day saw a sharp increase in confirmed cases, which surged to 210. On March 11, 2020, the World Health Organization (WHO) declared COVID-19 a pandemic. Shortly after, Scotland reported its first COVID-19-related death on March 14, 2020 [16, 28, 43]. To understand the impact of COVID-19 on patients and evaluate if different groups were affected differently, numerous studies analyzed patient data based on geography, clinical specialties, and demographics [17, 39, 59]. Scientists and mathematicians have conducted extensive research to mitigate the effects of COVID-19 [25, 58, 64]. Mathematical models have been created to explore how the virus affects blood flow. Blood comprises white and red blood cells, platelets, and is suspended in plasma. The proportion of red blood cells is indicated by the hematocrit level [2, 66, 78]. COVID-19 patients often face complications like blood clotting or bacterial infections, which can be managed with antibiotics to lower the risk of heart disease [37, 40, 77]. Hydroxychloroquine, traditionally used for malaria, lupus, and rheumatoid arthritis, has been found to help reduce the formation of blood clots in the cardiovascular system, thereby lowering the risk of heart attacks and strokes [19, 48, 62]. Conditions such as atherosclerosis or stenosis can impair blood flow and are significant contributors to cardiovascular diseases. Atherosclerosis is a leading cause of death in many countries due to its role in blocking blood vessels and causing heart diseases [7, 15, 26, 41,]. When healthcare professionals refer to "cardiovascular disease, " they typically mean disorders caused by atheroma, stenosis, or atherosclerosis, which affect the heart or blood vessels. Numerous researchers [12, 38, 57] have explored how overlapping stenosis impacts blood flow parameters in narrow blood vessels. Typically, these studies have used models with tubes of uniform cross-section to analyze stenosis effects. However, in reality, biological and physiological ducts are often inclined and have non-uniform cross-sections. Studies such as those by [3, 11, 20, 49] have addressed this by employing the Herschel-Bulkley fluid model to examine multiple stenoses in inclined tubes with varying cross-sections, assessing their impact on blood flow parameters. Other researchers [1, 5, 24, 67] have used mathematical modeling to treat blood as a non-Newtonian fluid, investigating its various effects under these conditions. Recent research has employed numerical models to understand the impact of stenoses on blood flow, specifically using the Bingham plastic fluid model to represent blood behavior. Some studies [6, 14, 23, 65,] focused on irregular arterial mild stenosis and demonstrated that the presence of stenoses reduces fluid velocity.

Mathematical Modeling of Arterial Blood Flow

The blood flow has consider laminar, fully develop an axially symmetric, through a non-uniform cross-section. The momentum equation is given by [11, 18, 22, 50]:

$$\frac{1}{r}\frac{\partial}{\partial r}(r\tau_{rz}) = -\frac{\partial p}{\partial z} + \frac{sin\alpha}{F} \quad (1)$$

$$F = \frac{\mu U^n}{\rho g R_0^{n+1}} \quad (2)$$

τ_{rz} = Shear stress,

The constitutive equations for the Prandalt fluid model is given by [9, 45, 34]:

$$\bar{S} = \frac{A\sin^{-1}\left\{\frac{1}{c_1}\left[\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial w}{\partial z}\right)^2\right]^{\frac{1}{2}}\right\}}{\left[\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial w}{\partial z}\right)^2\right]^{\frac{1}{2}}}\frac{\partial w}{\partial r} \quad (3)$$

By using boundary conditions [15, 21, 32, 36]:

τ is finite at r=0, (4)

u=0 at r=h (z) (5)

The non-dimensional variable are as follows [46, 72]:

$$\bar{z} = \frac{z}{L}, \bar{\delta} = \frac{\delta}{R_0}, \bar{R}(z) = \frac{R(z)}{R_0}, \bar{P} = \frac{p}{\left(\frac{\mu UL}{R_0^2}\right)}, \bar{\tau}_0 = \frac{\tau_0}{\mu\left(\frac{U}{R_0}\right)}, \bar{\tau}_{rz} = \frac{\tau_{rz}}{\mu\left(\frac{U}{R_0}\right)}, \bar{Q} = \frac{Q}{\pi R_0^2} \quad \bar{F} = \frac{F}{\mu U\lambda}$$

The mathematical expression for the geometry of the stenoses in non-dimensional is [47, 79,]:

$$h(z) = \mathrm{d}(z)\left[1 - k\left(b^{n-1}(z-a) - (z-a)^n\right)\right];$$

$$a < z \le a + b$$

$=d\ (z);$ otherwise (6)

$$\varepsilon(z) = \mathrm{d}(z)\left[c + \sigma e^{-\Pi^2(z-z_d-0.5)^2}\right];\ a < z \le a + b$$

$=c\ d\ (z);$ otherwise (7)

With $d\ (z) = R_0 + \xi z$ (8)

In the above equations $d\ (z)$ is the radius of the arterial segment in the stenotic region.

$$k = \frac{\delta^*}{R_0 b^n}\frac{n^{\frac{n}{n-1}}}{n-1} \quad (9)$$

1). $R_e\frac{\delta^* n^{\frac{1}{n-1}}}{b} << 1$ .2). $\frac{R_0 n^{\frac{1}{n-1}}}{b} \approx o(1)$

And for mild stenosis $\left(\frac{\delta^*}{d_0} << 1\right)$ the flow governing equations takes the form (after dropping the dashes for the sake of convenience).

Solution of the problem: The velocity has obtained by simplifying and integrating the Eqs. (1) and (3) with the help of boundary conditions (4),

$$u = \frac{(P+f)}{\mu}\left[\frac{r^2-h^2}{4} + \frac{\tau_0}{(P+h)}(r-h) - \frac{2\sqrt[2]{2}}{3}\left(r^{3/2} - h^{3/2}\right)\left(\frac{\tau_0}{(P+f)}\right)^{1/2}\right] \quad (10)$$

The flow rate for the blood flow with transverse magnetic field is,

$$Q = \int_0^R 2\ \pi\ u\ r\ dr \quad (11)$$

By the help of equation (11) and equation (10), flow rate can,

$$Q = \frac{R_e\varepsilon}{2\mu}\left(\frac{\partial P}{\partial z}\right)\left[\frac{4\mu h}{h\varepsilon^2} + \left(\frac{8h+\varepsilon^2}{(1+h)}\right)r^2 + \frac{(15r+h^2)(8\varepsilon+h^2)}{\varepsilon^2} + \frac{h^2\varepsilon^2}{(2h+\varepsilon)} + \frac{(8\varepsilon r+3h^2)(2\varepsilon+h^2)}{R^2}\right] \quad (12)$$

$$\Delta p = \int_0^L \left(\frac{dp}{dz}\right)dz = \left(\frac{8\mu Q}{\pi R_0^4}\psi\right) \quad (13)$$

The dimensionless expression for resistance to flow, using;

$$\lambda = \left(\frac{P_i - P_0}{Q}\right) \quad (14)$$

$$\lambda = \left(\frac{R_e\varepsilon}{8\mu}\right)^2\left(\frac{8h}{3\pi hr}\right)\left[\frac{4\mu h}{h\varepsilon^2} + \left(\frac{2+h\varepsilon^2}{8\varepsilon}\right)r^2 + \frac{(15r\varepsilon - 2h + h^2)(1+h^2)}{3h^2\varepsilon^2} + \left(\frac{2\varepsilon^2}{(h+\varepsilon)}\right) + \frac{(7\varepsilon r + 3(\varepsilon-h)h^2)(4\varepsilon - h^2)}{h^2}\right] \quad (15)$$

Wall shearing stress:

$$\tau = (\frac{2R_e\varepsilon^{2}}{r^2})^2(\frac{4r^2(h+2\varepsilon)}{(1+\varepsilon^2)})[(\frac{3+\varepsilon^2}{(1+h^2)})r^2 + \frac{(15r\varepsilon - 2h + h^2)(1+h^2)}{(1+h^2\varepsilon^2)} + (\frac{2\varepsilon^2}{(3+\varepsilon)^2}) + \frac{(\varepsilon r + 3h)}{1+h^2}] \quad (16)$$

2. Results and Discussion

Irregular growth of stenosis in the arteries significantly affects blood flow in the heart and can lead to severe cardiovascular conditions. This abnormal narrowing of the arteries is primarily caused by the buildup of lipids or fats on the inner walls of blood vessels. Stenosis can result in various health issues, including brain hemorrhage, high blood pressure, heart attacks, and atherosclerosis. In this paper, we examined the effects of blood viscosity, shear stress, resistance to flow, and pressure in blood vessels [53, 60, 70, 82, 86]. The goal of our research is to explore how treating COVID-19 patients with high blood viscosity using Hydroxychloroquine and Doxycycline can improve blood flow through the vessels. To assess the impact of different parameters involved in this study, MATLAB programs have been developed. These programs estimate critical outcomes related to pressure profiles, apparent viscosity, and resistance to blood flow under both diseased and normal conditions [55, 69, 81].

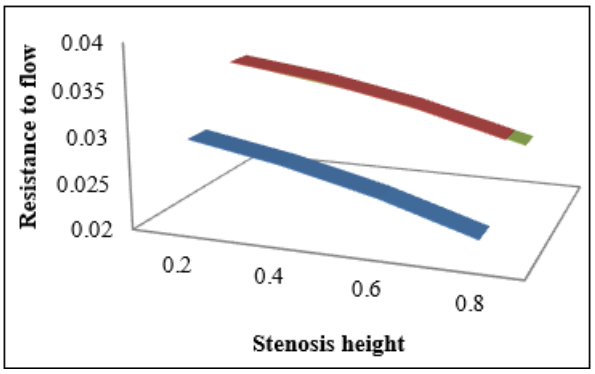

Figure 1: Variation of resistance to flow with stenosis height

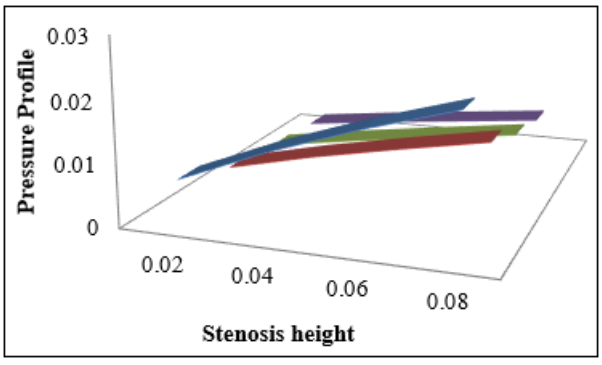

Figure 2: Variation of Pressure with stenosis height

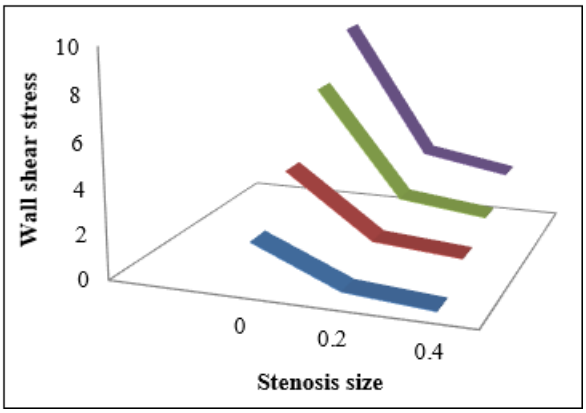

Figure 3: Variation of wall shear stress with stenosis size

The results of this research are illustrated in Figures.1-3, which utilize tentative data values within blood vessels [61, 76, 85, 88]. Figure.1. shows that resistance increases as the size of the stenosis grows or as the artery radius decreases, confirming that larger stenosis leads to higher resistance. Figure.2. demonstrates that pressure also rises with increasing stenosis size, a trend consistent with previous findings. Lastly, Figure.3. shows that wall shear stress increases with the growth of stenosis size, highlighting that smaller artery radii lead to higher stress levels. From these figures, it is evident that pressure gradient, resistance and wall shear stress are crucial factors directly influenced by blood flow through the vessels [51, 54, 80, 89, 90]. In regions with stenosis, resistance escalates as the stenosis progresses and remains stable in non-stenotic areas. As stenosis size increases, so does the pressure within the artery, leading to greater heat generation inside the vessel [73, 84, 87]. This effect is more pronounced in arteries that converge compared to those that diverge. In diabetic patients, the resistance to blood flow is higher than in non-diabetic patients, making them more susceptible to high blood pressure, heart diseases, and complications such as COVID-19. For these patients, managing blood flow resistance and pressure can be achieved by reducing plasma viscosity [52, 68, 71, 75, 83, 91]. Hydroxychloroquine, a drug known to lower blood viscosity, can enhance blood flow by reducing the overall viscosity of the blood. Regular doses of hydroxychloroquine can effectively lower plasma viscosity, thereby improving blood flow and potentially mitigating the risks associated with high resistance and blood pressure.

3. Conclusion

Understanding the dynamics of arterial blood flow through mathematical modeling provides valuable insights into the relationship between cardiovascular health and COVID-19. By integrating these insights into public health strategies, we can develop more effective approaches to preventing and managing the impacts of COVID-19. In this study, it has been observed that resistance decreases as the size of stenosis decreases in the fluid model used. This analysis expands on

understanding the flow dynamics of blood with increased viscosity and emphasizes the role of Hydroxychloroquine and Doxycycline in preventing and treating blood clotting in COVID-19 patients. Blood flow in COVID-19 patients is typically higher compared to normal patients. Therefore, COVID-19 patients with increased flow resistance are more susceptible to conditions like high blood pressure, heart attacks, inflammation, and lung infections. Managing plasma viscosity through medication can help reduce blood viscosity and flow resistance. Hydroxychloroquine, in combination with Doxycycline, represents an effective treatment option for patients with heart disorders, reducing plasma viscosity and addressing inflammation and respiratory infections effectively. This holistic approach, combining mathematical analysis, clinical insights, and preventive healthcare, offers a robust framework for enhancing both individual and public health in the face of the ongoing pandemic.

References

[1] Akbar, S., Shah, S. R., "DURYSTA" the first biodegradable sustained release implant for the treatment of open-angle glaucoma, Int. J. of Frontiers in Bio. and Pharm Res., 01 (02), 1-7, 2021.
[2] Akbar, S., Shah, S. R., "Mathematical Modeling of Blood Flow Dynamics in the Cardiovascular System: Assumptions, Considerations, and Simulation Results", Journal of Current Medical Research and Opinion, 7 (4), 2216-2225, (2024).
[3] Akbar, S., Shah, S. R., "The Effects of Prostaglandin Analogs on Intraocular Pressure (IOP) in Human Eye for Open Angle Glaucoma. Int. J. of Innovative Tech. and Exploring Eng., 10 (2), 176-180, (2020).
[4] Anamika, Shah, S. R., "Mathematical and Computational study of blood flow through diseased artery", Int. J. of Computer Science, 5, (6), 1-6, (2017).
[5] Anamika, Shah, S. R., Anuradha "Bio-Computational analysis of blood flow through two phase artery", Int. J. of Engineering Science and Computing, 7, (6), 13397-213401, (2017).
[6] Anamika, Shah, S. R., Kumar, R., "Mathematical Modelling of blood flow through tapered stenosed artery with the suspension of nanoparticles using Jeffrey fluid model", International journal of development research, 07, 06, 13494-13500, (2017).
[7] Anamika, Shah, S. R., Singh A., "Mathematical Modelling Of Blood Flow through Three Layered Stenosed Artery", Int. J. for Res. in Appl. Sci. and Eng. Tech., 5, (6), 1-6, (2017).
[8] Anuradha S,, Shah, S. R., Siddiqui, S. U., "Effects of inclined multi-stenoses arteries on blood flow characteristics using bingham plastic fluid", Int. J. for Mathematics, 1, (12), 7-14, (2015).
[9] Anuradha S., Shah, S. R., S. U. Siddiqui, "Mathematical Modeling and Numerical Simulation of Blood Flow through Tapered Artery", International Journal of Innovative Science, Engineering & Technology, 3, (2), 710-717, (2016).
[10] Anuradha S., Shah, S. R., S. U. Siddiqui, "Performance of blood flow through two phase stenosed artery using Herschel-Bulkley model", Int. Journal of Applied And Pure Science and Agriculture, 2, (2), 228-240, (2016).
[11] Anuradha S., Shah, S. R., Siddiqui, S. U., "Mathematical Modelling and Analysis of Blood Flow through Diseased Blood Vessels", International Journal of Engineering and Management Research, 5, (6), 366-372, (2015).
[12] Anuradha, S., Shah, S. R., Siddiqui, S. U., "A Mathematical Model to study the similarities of blood fluid models through inclined multi-stenosed artery", Int. J. of Eng. Research and Modern Edu., 2, (1), 108-115, (2017).
[13] Chaturvedi, P. and Shah, S. R. "Role of crizanlizumab for sicke red cells disease", International Journal of Biology, Pharmacy and Allied Sciences, 12 (3), 1147-1157, (2023).
[14] Chaturvedi, P., Kumar, R., Shah, S. R., "Bio-Mechanical and Bio-Rheological Aspects of Sickle Red Cells in Microcirculation: A Math. Mod. Approach, Fluids, 2021, 6, 322, 01-15.
[15] Chaturvedi, P., Shah, S. R., "Mathematical Analysis for the Flow of Sickle Red Blood Cells in Microvessels for Bio Medical Application, Yale J. of Bio. and Medicine, 96 (1), (2023), 13-21.
[16] Chaturvedi, P., Shah, S. R., Akbar, S., Kumar, R., "Prospective of Hydroxychloroquine and Zinc with Azithromycin for Nanoparticles Blood Flow in Covid-19 Patients, Int. J. of Nanotechnology in Medicine & Engineering, 6 (1), 01-07, (2021).
[17] Geeta, Siddiqui, S. U., Sapna, "Mathematical Modelling of blood flow through catheterized artery under the influence of body acceleration with slip velocity", Application and applied Math. An Int. J., 8 (2), 481-494, (2013).
[18] Geeta, Siddiqui, S. U., Shah, S. R., "A Biomechanical approach to the effect of body acceleration through stenotic artery", Applied Math. and Computation, 109 (1), 27-41, (2015).
[19] Geeta, Siddiqui, S. U., Shah, S. R., "Effect of body acceleration and slip velocity on the pulsatile flow of casson fluid through stenosed artery"Adv. Appl. Sci. Res.5 (3), 231-225, (2014).
[20] Geeta, Siddiqui, S. U., Shah, S. R., "A Mathematical Model for two layered pulsatile blood flow through stenosed arteries", E-Journal of Sci. and Technology, 109 (11), 27-41, (2015).
[21] Gupta, P., Akbar, S., Shah, S. R., Alshehri, Mo., Sharma, S. K., and "A Mathematical Study for Promoting Disability Inclusion in Glaucoma: A Comprehensive Approach", J. of Disability Res.3, 1-12, (2024).
[22] Islam S. M. N., Sadique, Mo., Shah, S. R., Sharma, S. K., "Effect of Significant Parameters on Squeeze Film Characteristics in Pathological Synovial Joints", Math., 11 (1468) 1-23, (2023).
[23] Jaiswal., K. M., Shabab Akbar and Shah S. R., Mo. Sadique "Exploring capillary-tissue fluid exchange: Insights into red cell deformation in narrow vessels and its clinical implications", International Journal of Fauna and Biological Studies, 11 (3), 4-14, (2024).
[24] Kasturia, P., Rohit Kumar Sharma, Purnima Chaturvedi, Ravins Dohre, Shah, S. R., "Efficacy of venetoclax and azacitidine for targeting leukemic stem cell in acute myeloid leukemia", International Journal

of Biology, Pharmacy and Allied Sciences, 13 (6), 3072-3090, (2024).
[25] Kaur, H., Prithvi Singh, Rubi Solanki, Alvea Tasneem, Simran Suri, Shah, S. R., Ravins Dohare, "Screening of miRNAs as prognostic biomarkers and their associated hub targets across Hepatocellular carcinoma using survival-based bioinformatics approach", Journal of Genetic Engineering and Biotechnology, 22 (1), 1-10, (2024).
[26] Kumar V., and Shah, S. R., "Mathematical model to study the heat transfer between core and skin", SRMS, Journal of Mathematical Sciences, 7, 7-12, (2024).
[27] Kumar, J. P., Sadique, Mo. Shah, S. R.,, "Mathematical study of blood flow through blood vessels under diseased condition, Int. J. of Multidisciplinary Res. & Dev., 9 (6), (2022), 31-44.
[28] Kumar, P, Shah, S. R., "A Hydromechanical Perspective to Study the Effect of Body Acceleration through Stenosed Artery", Int. J. of mathematical engineering and management sciences, 6 (5), 1381-1390, (2021).
[29] Kumar, R., Shah, S. R., "A mathematical approach to study the blood flow through tapered stenosed artery with the suspension of nanoparticles" Destech Transactions on Engineering and Tech. Research, 01, 1-6, (2017).
[30] Kumar, R., Shah, S. R., "Mathematical Modeling of Blood Flow with the Suspension of Nanoparticles Through a Tapered Artery With a Blood Clot", Frontiers in Nanotech., 2, 596475, 1-5, (2020).
[31] Kumar, R., Shah, S. R., "Performance of blood flow with suspension of nanoparticles though tapered stenosed artery for jeffrey fluid model" Int. J. Nanosci., 17 (6), 1850004 (1-7), (2018).
[32] Kumar, R., Shah, S. R., "Study of blood flow with suspension of nanoparticles through tapered stenosed artery", Global J. of Pure and Applied Mathematics, 13 (10), 7387-7399, (2017).
[33] Kumar, V., and Shah, S. R., "Mathematical modelling to study the heat transfer between core and skin", SRMS, Journal of Mathematical Sciences, 7 (2021), 7-12, (2024).
[34] Kumar, V., Shah, S. R., "A mathematical approach to investigate the temperature distribution on skin surface with sinusoidal heat flux condition, Int. J. of Multidisciplinary Research and Development, 9 (5), (2022), 141-146.
[35] Kumar, V., Shah, S. R., "A Mathematical study for heat transfer phenomenological processes in human skin", Int. J. of Mechanical Eng., 7 (6), (2022), 683-692.
[36] Kumar, V., Shah, S. R., "Thermobiological Mathematical Model for the study of temperature response after cooling effects", ssrg, Int. J. of Applied physics, 9 (2), (2022), 7-11.
[37] Lenin, J. S., Shah S. R., "Mathematical Analysis of Stem Cell Dynamics in Acute Myeloid Leukemia: Towards Precision Medicine Strategies, Int. J. of Sci. &Res.13 (05), 528-535, (2024).
[38] Mahesh, Arya, S., Shah, S. R., "Optimizing cardiovascular health: ayurvedic insights into blood flow through normal and stenosed arteries, Int. Journal of AYUSH, 13 (5), 18-35, (2024).
[39] Majhi, L., Sudheer Arya Sapna Ratan Shah, "Exploring Shilajatu's Therapeutic Potential in Diabetes Management: A Comprehensive Study Integrating Ayurvedic Wisdom and Modern Science", International Journal of Science and Research (IJSR), 13 (5), 1374-1380, (2024).
[40] Malik, M., Z., Kumar, R., Shah, S. R.,, "Effects of (Un) lockdown on COVID-19 transmission: A mathematical study of different phases in India, medRxiv The preprint server health Sci., 1-13, (2020).
[41] Mo. Sadique and Shah, S. R., "Mathematical model to study the study the squeeze film characteristics of synovial joints in diseased human knee joint", World Scientific Annual Review of Biomechanics, 1 (2330004) 1-21, (2023).
[42] Mo., Sadique, Shah, S. R.,, "Mathematical model to study the effect of PRG4, hyaluronic acid and lubricin on squeeze film characteristics of diseased synovial joint", Int. J. of Mechanical Eng., 7 (6), 2022, 832-848.
[43] Purnima C., Shah, S. R., "Assessing the Clinical Outcomes of Voxelotor Treatment in Patients with Sickle Cell Disease", Int. J. of Applied Science and Biotechnology, 12 (1), 46-53, (2024).
[44] Sadique, Mo., Shah, S. R.,, "Mathematical study for the synovial fluid flow in Osteoarthritic knee joint, Journal of Engineering and Applied Sciences, 17 (2), (2022), 15-21.
[45] Sapna, Siddiqui, S. U., "Study of blood flow through a stenosed capillary using Casson's fluid model", Ultra Science, Int. J of physical sciences, 16, (2) 133-142, (2004).
[46] Shabab A., Shah, S. R., "Mathematical Modeling of Blood Flow Dynamics in the Cardiovascular System: Assumptions, Considerations, and Simulation Results", Journal of Current Medical Research and Opinion, 7 (4), 2216-2225, (2024).
[47] Shah, S. R., "A biomechanical approach for the study of deformation of red cells in narrow capillaries", IJE: Transaction A: Basics, 25 (4), 303-313, (2012).
[48] Shah, S. R., "A biomechanical approach for the study of Two-phase blood flow through stenosed artery", Int. J. of research studies in biosciences, 1 (2), 24-32, (2013).
[49] Shah, S. R., "A case study of non-Newtonian viscosity of blood through artherosclerotic artery", The cardiology, 6 (2), 11-17, (2011).
[50] Shah, S. R., "A Mathematical Model for the analysis of blood flow through diseased blood vessels under the influence of porous parameter", J. of Biosci. & Tech., 4 (6), 534-541, (2013).
[51] Shah, S. R., "A mathematical study of blood flow through radially non-symmetric multiple stenosed arteries under the influence of magnetic field", Int. J. of Advanced Research in Biological Sciences, 2 (12), 379-386, (2015)
[52] Shah, S. R., "A mathematical study of blood flow through stenosed artery", International Journal of Universal Science and Engineering, 1 (1), 26-37, (2015).
[53] Shah, S. R., "A study of blood flow through multiple atherosclerotic arteries", Int. J. for Mathematics, 1, (12), 1-6, (2015).

[54] Shah, S. R., "A study of effects of magnetic field on modified Power-law fluid in modeled stenosed artery" Journal of Bioscience and Technology, 1 (4), 187-196, (2010).
[55] Shah, S. R., "An innovative solution for the problem of blood flow through stenosed artery using generalized bingham plastic fluid model", Int. J. of research in applied and natural social sci., (2013) 1 (3), 97-140.
[56] Shah, S. R., "An innovative study for non-Newtonian behavior of blood flow in stenosed artery using Herschel-Bulkely flud", Int. J. of biosiences and biotechnology, 5 (5), 233-240, (2013).
[57] Shah, S. R., "Capillary-tissue diffusion phenomena for blood flow through a stenosed artery using herschel-bulkley fluid" Int. J of Res. in Biochem. and Biophy., 1 (1).1-8 (2011).
[58] Shah, S. R., "Effect of clopidogrel on blood flow through stenosed artery under diseased condition", Int. J. of Experimental Pharmacology, 4 (1), 887-893, (2014).
[59] Shah, S. R., "Effects of Acetylsalicylic Acid on blood flow through an artery under Atherosclerotic condition", Int. J. of Molecular medicine and advances sci.7 (6), 19-24, (2011).
[60] Shah, S. R., "Effects of antiplatelet drugs on blood flow through stenosed blood vessels", Journal of Biomimetics, Biomaterials and Tissue Engineering, 18, 21-27, (2013).
[61] Shah, S. R., "Impact of radially non-symmetric multiple stenoses on blood flow through an artery", International Journal of Physical and Social Sciences, 1 (3), 1-16, (2011).
[62] Shah, S. R., "Mathematical analysis of blood flow through atherosclerotic arterial segment having non-symmetric mild stenosis". Int. J. of Rese. in Pure and Appl. Phy., (1) 1-5, (2011).
[63] Shah, S. R., "Mathematical Study of Blood Flow through Atherosclerotic Artery in the Presence of Porous Effect", Int. J. of Modern Sciences and Eng. Tech., 2, (12), 12-20, (2015).
[64] Shah, S. R., "Non-Newtonian flow of blood through an atherosclerotic artery", Research journal of applied sciences.6 (1), 76-80, (2011).
[65] Shah, S. R., "Performance modeling and analysis of magnetic field on nutritional transport capillary tissue system using modified Herschel-Bulkely fluid", Int. J. of Advanced research in physical sciences, 1 (1).33-41, (2014).
[66] Shah, S. R., "Performance Study on Capillary-Tissue Diffusion Phenomena for Blood Flow through Stenosed Blood Vessels", American J. of Pharmtech Res., 2 (2), 695-705, (2012).
[67] Shah, S. R., "Response of blood flow through an atherosclerotic *artery* in the presence of magnetic field using Bingham plastic fluid" Int. J. of Pha. & Biomed. Res.2 (3), 96-106, (2011).
[68] Shah, S. R., "Role of Non-Newtonian behavior in blood flow through normal and stenosed artery", Research journal of Biological sciences, 6 (9), 453-458, (2011).
[69] Shah, S. R., "Significance of Aspirin on Blood Flow to Prevent Blood Clotting through Inclined Multi-Stenosed Artery", Letters In Health and Biological Sciences, 2 (2), 97-100, (2017).
[70] Shah, S. R., "Study of dispersion of drug in blood flow with the impact of chemical reaction through stenosed artery", International journal of Biosciences, 21 (3), 2022, 21-29.
[71] Shah, S. R., "Study of modified Casson's fluid model in modeled normal and stenotic capillary-tissue diffusion phenomena" Int. J. of Comput. Eng. & management,.11, 51-57, (2011).
[72] Shah, S. R., Akbar, S., "Mathematical Study for the Outflow of Aqueous Humor and Function in the Eye", Int. Journal of Scientific & Engineering Research 11 (10), 743-750, October-2020.
[73] Shah, S. R., and Anamika, "A mathematical model of blood flow through diseased blood vessel", Int. J. of Emerging Trends and Tech. in Computer Science, 6, (3), 282-286, (2017).
[74] Shah, S. R., Clinical influence of hydroxychloroquine with azithromycin on blood flow through blood vessels for the prevention and Treatment of covid-19, International journal of biology, pharmacy and allied science. (2021), 10 (7): 2195-2204.
[75] Sharma, S. K., Alshehri, Mo., Priya Gupta and Shah, S. R., "Empowering the visually impaired: Translating Handwritten Digits into Spoken Language with HRNN-GOA and Haralick Features", Journal of Disability Research, 3, 1-21, (2024).
[76] Siddiqui, S. U., Shah, S. R., "A Physiologic Model for the problem of blood flow through Diseases blood vessels", Int. J of advances in Applied Sciences, 5 (2), 58-64, (2016).
[77] Siddiqui, S. U., Shah, S. R., "Achievement of Pentoxifylline for Blood Flow through Stenosed Artery", J. of Biomimetics, Biomaterials and Tissue Engineering, 13.81-89, (2012).
[78] Siddiqui, S. U., Shah, S. R., "Two-phase model for the study of blood flow through stenosed artery, International Journal of Pharmacy and Biological Sciences, 1 (3), 246-254, (2011).
[79] Siddiqui, S. U., Shah, S. R., Geeta, "A Computational Analysis of a Two-Fluid non-Linear Mathematical model of pulsatile blood flow through Constricted Artery", E-Journal of science and Technology, 10 (4), 65-78, (2015).
[80] Siddiqui, S. U., Shah, S. R., "A Comparative Study for the Non-Newtonian Behaviour of Blood Flow through Atherosclerotic Arterial Segment", Int. J. of Pharmaceutical Sci. Review and Res., 9 (2), 120-125, (2011).
[81] Siddiqui, S. U., Singh, A., Shah, S. R., "Mathematical Modeling of peristaltic blood flow through a vertical blood vessel using prandtl fluid model", Int. J. of Mathematics and Computer Research, 4, (9), 710-717, (2016).
[82] Singh, S., "A mathematical model for modified herschel-bulkley fluid in modeled stenosed artery under the effect of magnetic field", Int. J. of Bioeng. & Tech. 1 (1), 37-42. (2010).
[83] Singh, S., "A two-layered model for the analysis of arterial rheology" International Journal of Computer Science and Information Technology, 4, 37-42. (2011).

[84] Singh, S., "Clinical significance of aspirin on blood flow through stenotic blood vessels" Journal of Biomimetics, Biomaterials and Tissue Engineering, 10, 17-24, (2011).
[85] Singh, S., "Effects of shape of stenosis on arterial rheology under the influence of applied magnetic field" Int. J. of Biomedical Eng. and Tech., 6 (3) 286-294, (2011).
[86] Singh, S., "Influence of magnetic field on blood flow through stenosed artery using casson's fluid model", Int. J. of BioEngineering, CardioPulmonary Sci. and Tech., 1, 1-7, (2010).
[87] Singh, S., "Numerical modeling of two-layered micropolar fluid through a normal and stenosed artery", Int. J. Eng., 24 (2), 177-187, (2011).
[88] Singh, S., "Numerical modelling for the modified Power-law fluid in stenotic capillary-tissue diffusion phenomena", Archives of Applied Science Resaerch, An Int. peer reviewed J. of appl. sci., 2 (1) 104-112, (2010).
[89] Singh, S., "The effect of Saline Water on viscosity of blood through stenosed blood vessels using Casson's fluid model", J. of Biomimetics, Biomaterials and Tissue Eng.,.9 37-45, (2011).
[90] Singh, S., and Shah, R. R., "A numerical model for the effect of stenosis shape on blood flow through an artery using power-law fluid", Advance in applied science research, An Int. peer reviewed J. of Sci., 1, 66-73, (2010).
[91] Stiehl, T., Kumar, R., Shah, S. R., "Understanding the impact of feedback regulations on blood cell production and leukemia dynamics using model analysis and simulation of clinically relevant scenarios", Applied Mathematical Modelling, (2024).