Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 46 No. 7
July 2025

A Mathematical Model for the Prevention of Heart Attack Under the Velocity of Blood Flow in Arteries

Rajan Kumar Sharma[1], Pradeep Kumar Singh[2], Sudhir Singh[3]& Vaibhav Kumar[4]

[1, 2] Department of Basic Sciences and Humanities,

Pranveer Singh Institute of Technology, Kanpur-209305, U. P.- India.

[3, 4] Department of Applied Science,

. KCC Institute of Technology and Management, Greater Noida,U.P.-India

[1] Corresponding Author

Abstract:

The human heart is a muscular organ that beats approximately 1 lakh times a day. Our heart is situated towards the left side of the chest, which pumps approximately 5000 gallons of blood throughout the body in a day. The way the human heart operates is to give oxygen and nutrients to tissues in the body. If the human heart fails to fulfil these conditions, the result can be fate for life. If blood flow in the heart is not running smoothly then heart attack occurs due to a significantly reduced or blocked heart. This blockage usually develops from the development of layers of fat, cholesterol, and other substances in the heart's (coronary) arteries.. The word for cholesterol is plaque. blood artery deposits. Plaque buildup is referred to as atherosclerosis. Sometimes plaque can burst and collect in blood vessels, blocking blood flow. Insufficient blood flow can cause damage or even death to a section of the heart muscle. In the present work, an attempt has been made to assess the required velocity owing to blood flow and the effect of resistance of flow of blood into the blood vessels that cause heart- attacks in humans by mathematical model.

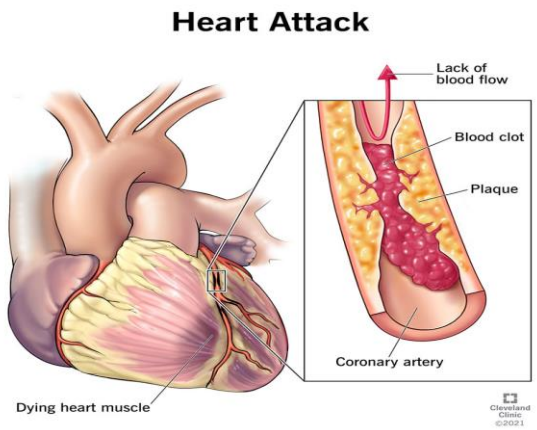
Keywords: Cardiovascular diseases; Cardiovascular system; Heart failure; Blood vessels, Blood pressure, Cholesterol.

Introduction:

Cells are suspended in plasma, an aqueous solution made up of 90% H2 O and 7% protein, to form blood Erthrocytes, which comprise 95% of the cells in a healthy human body, are principally in charge of carrying carbon dioxide from the body's metabolic processes to the lungs, where red blood cells make up 45% of the blood volume, and oxygen from the lungs to every cell in the body.. We refer to this portion as the hematocrit. Leucocytes, or white blood cells, make up around one-sixth of the total and are crucial for the body's ability to fend off infections. The platelets that contribute to blood coagulation make up 5% of the total. By dissolving in plasma and attaching itself to hemoglobin in red blood cells, oxygen is transported by blood. The heart pumps blood to the body's various organs through its elastic, muscular walls, which are continuously rhythmically made up of arteries and art. The aberrant growth that causes an artery's lumen to narrow is called stenosis. Significant cardiovascular issues may arise from this, as it may reduce or stop the blood supply. In the same way that myocardial infraction in the coronary arteries giving blood to the brain can result in heart failure, cerebral stokes can be caused by acute stenosis in the arteries delivering blood to the brain.. The greatest cause of death in the US, coronary artery disease (CAD), is the most common cause of heart attacks. Because arteries have strong walls made of muscle tissue and veins have thinner walls and require valves to keep blood flowing, arteries convey oxygenated blood away from the heart and veins carry deoxygenated blood towards the heart, with the exception of pulmonary blood vessels. Stenosis is the term used to describe the aberrant growth that reduces an artery's lumen. Due to circulatory disorders that decrease the blood supply, coronary arteries that supply blood to the brain may experience cerebral stokes due to ischemic stenosis, and coronary arteries that supply blood to the brain may also experience cerebal stokes

due to mayocardial infraction, which can result in heart failure. MI, or myocardial infarction, often referred to as a heart attack, this condition happens when the heart's blood supply is cut off or diminished, depriving the heart muscle of oxygen and leading to cell death. Coronary artery disease (CAD), the leading cause of death in the US, is the most frequent cause of heart attacks. In the human body, veins convey blood toward the heart while arteries carry blood away from it. Arteries transport oxygenated blood, while veins transport deoxygenated blood, with the exception of pulmonary blood vessels. Muscle tissue makes up the thick walls of arteries. Veins require valves to maintain blood flow since their walls are thinner. Arteries and veins are different blood vessels that carry blood from the heart to the body's other organs. While veins return low-oxygen blood to the heart, arteries transport oxygen-rich blood away from the heart. Arteries are thick, muscular, and have a tight, cylindrical shape. Veins may appear deformed or collapsed due to their thinner and less elastic nature. While arteries can withstand the high pressure of blood flow, veins are part of a low-pressure system. Arteries have a lower carbon dioxide content and a higher oxygen content than veins. Any change to the blood vessels or their characteristics might change blood flow and cause anything from little discomfort to death. The cardiovascular system is composed of the heart and its blood vessels **[1].** The cardiovascular system, which moves blood throughout the body, includes blood vessels. Capillaries, arteries, and veins are the three main forms of blood vessels.

Fig 1



Source: A heart attack is brought on by a blocked coronary artery, which stops blood flow to the heart muscle. In 2021, Cleveland Clinic

The heart disease, that is cardiovascular risk factors, including smoking, physical activity, sleep, and obesity and health factors including cholesterol, blood pressure, glucose control, and metabolic syndrome [**2**]. Heart attack symptoms can vary. Some folks just have minor symptoms. Others' symptoms are severe. Some folks have no symptoms at all. Unusual symptoms in women can include back, arm, or neck pain, ranging from mild to severe. Sudden cardiac arrest can occasionally be the initial sign of a heart attack. Men over 45 and women over 55 are at a higher risk of having a heart attack than younger men and women, according to risk factors for heart attacks.Tobacco use include both smoking and extended exposure to smoke. Give up smoking if you do.The main problems of high blood pressure to spend extra time involving in a work. The high blood pressure can gradually destroy the arteries in the heart. Obesity is another reason of high blood pressure due to high level of collection of cholesterol and fats and triglycerides which blockage the arteries and stands may be heart attack [**3**]. Due to effect of high blood pressure and collection of cholesterol layers or diabetes (Hyperlipidaemia) invites the symptoms of heart attack. In diabatic patients due to Blood sugar increases when the body does not make or use a hormone called insulin properly. Excessive anger and other emotional stressors can raise the risk of heart attacks and illegal drug use pregnancy-related high blood pressure increases the risk of heart disease.

One or more structural issues with the heart that exist from birth are known as congenital heart disease, or heart disease by birth. A condition known as congenital heart disease (CHD) affects how your heart develops prior to birth. It is commonly accepted that there are eight cases of CHD for every thousand live births **[4] & [5].**

Table 1 Top five reason of deaths in India classified by the areas of residence and gender:

Rank	India (	populations in	populations in	Male	Female	Age (2

	age of all groups)	Rural	urbans			5-69)year
First	1	1	1	1	1	1
Second	2	2	9	2	3	2
Third	3	3	2	4	2	4
Fourth	5	5	4	3	6	9
Fifth	6	6	7	5	7	8

Cardio Vascular=1, COPD, Asthma=2, Diarrhea=3, Tuberculosis=4, Perinatal=5,

Respiratory infections=6, Senility=7, Ill-defined=8, Cancer =9

Adapted from Registrar General of India Report [**6**]. COPD: Chronic obstructive pulmonary disease. In 2022, 32,457 people died from heart attacks in India, a 12.5% increase from 2021, when 28,413 people died. Some experts have linked the increase to the COVID-19 pandemic, which may have changed people's lifestyles and increased the risk of heart disease. Other factors that may contribute to the increase include: Poor diet, Sedentary lifestyle, Lack of physical activity, Tobacco use, Stress and anxiety, Diabetes, Hypertension, Inadequate healthcare [**7**] Infection from COVID-19 appeared to significantly increase the risk of heart attack, stroke, and death for up to three years among unvaccinated people early in the pandemic when the original SARS-CoV-2 virus strain emerged, according to a National Institutes of Health (NIH)-supported study[**8**]. With an age-standardized CVD death rate of 272 per 100,000 population, India has a higher burden of cardiovascular disease (CVD) than the world average, which is 235 per 100,000.. The non-communicable diseases commonly include cardiovascular disease (CVD), various cancers, chronic respiratory illnesses, diabetes, and so on which are estimated to account for around 60% of all deaths [**9**], [**10**] &

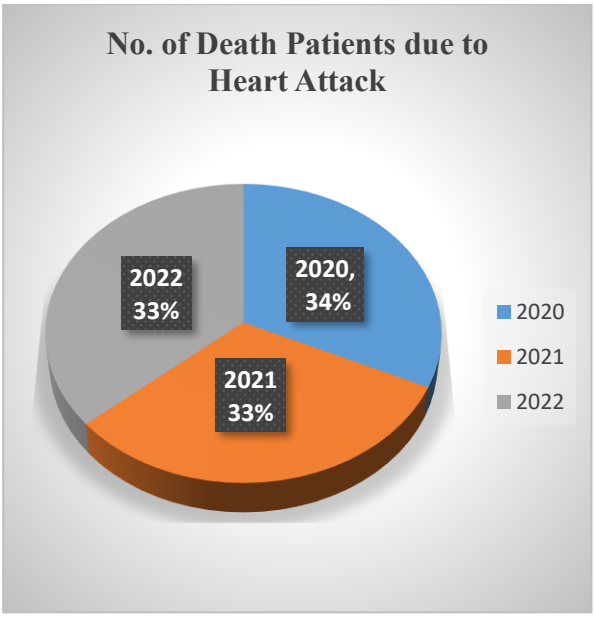
[**11**]. In India, paediatric cardiac care is not sufficient. We are lacking here globally. We have no data on congenital heart disease (CHD) prevalence at birth or mortality from CHD. Our governments provided different schemes, but this is not sufficient yet. The resources are limited, so we need to do more hard work in this field of paediatric cardiac surgery [**12**] &[**13**]

Table 2

Accidental Deaths and Suicides in India due to heart attack		
S. No.	**Year**	**No. of Death Patients**
1	2020	28,576
2	2021	28413
3	2022	32457

Source: Accidental Deaths and Suicides in India'

Fig 2



Source: Accidental Deaths and Suicides in India' report by the NCRB

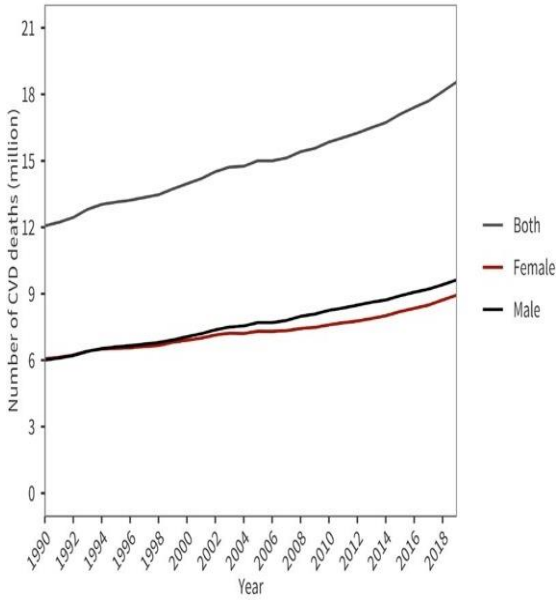
Global Mortality Burden of Cardiovascular Diseases:

The primary cause of death and a significant contributor to disability are cardiovascular diseases (CVDs). According to Figure 3, the estimated number of deaths worldwide from CVDs

rose from 12.1 million in 1990 (equally split between males and females) to 18.6 million in 2019 (9.6 million males and 8.9 million females).

Fig3:

The World trends linefor number of deaths

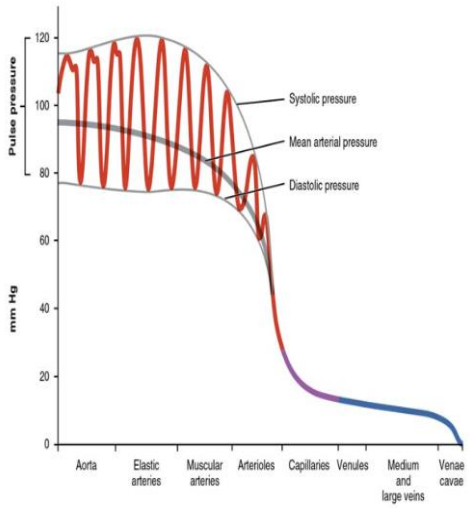


patientsby cardiovascular diseases from:1990-2019.

Source:(World Heart Report 2023) [**14**].

Fig 4: Systolic and Diastolic Blood Pressure

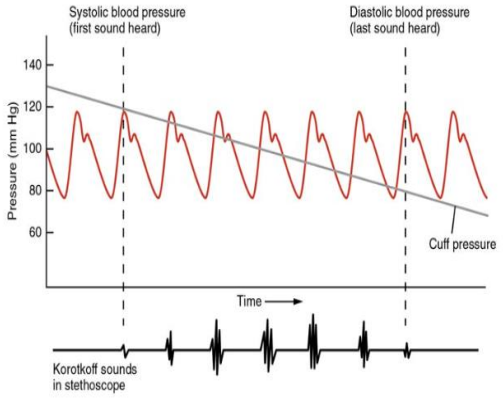
(The components of blood pressure in the blood vessels)



Source:.(Lumen BIO 103:Human Biology)

Fig 5:

(The measurement of blood pressure by systolic and diastolic pressures.)



Source..**(**Lumen BIO 103:Human Biology)

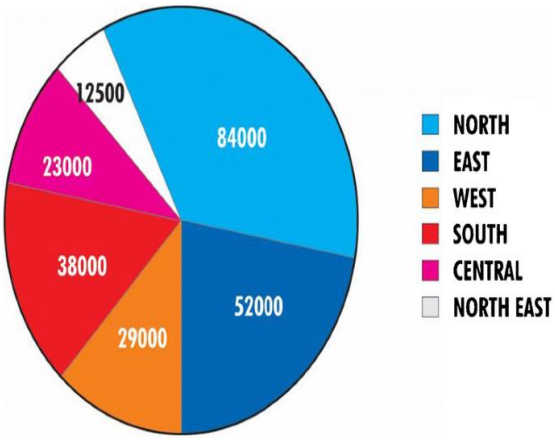
Regional Variations

The coronary heart disease (CHD) related to those patients in which the blood supply in blood vessels are not smoothly running because in blood vessels there are many blockages and obstacles due to fat, So the resistance due to blood is high rate on the wall of the blood vessels as the wall of the arteries may be coated with fats deposite. The Crude Birth rate of India in 2024 estimated to be 16.75 approx per one thousand people this is 1.18% decreases from 2023 when CBR was16.9 births per thousand population and the death rate of India is estimated as 66 per thousand. The infant mortality rate in 2024 is 25.79 death per thousand live births which is approx. 3% decreases compare to 2023.The congenital Heart disease in India mean the people who has effected from by birth there are 27 .5% of all cognital Heart disease CHD **[15]**. The people in rich country is remedial against its continuously but in India, it is a fetal disease. So to fight against it and find the good treatments for its prevention in basically in the middle and low income family is so coastally, that is the diagnosis is not easy, whenever this is 8 to 12 per thousand live births .

There are regional differences in crude birth rates and population in India. The Northern and Eastern regions of India (Delhi, Jammu and Kashmir, Punjab, Haryana, Himachal Pradesh, Rajasthan, Uttar Pradesh, Uttarakhand, Bihar, Jharkhand, Orissa, and West Bengal) have been found to have a significantly higher total number of live births

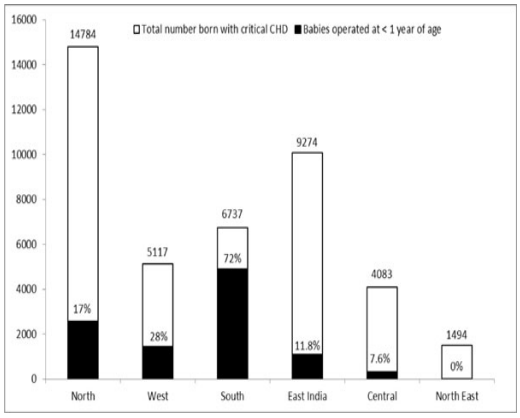
than the other four regions (Southern, Western, Central, and North-East). The overall number of newborns with congenital heart disease is probably high (Fig. 6).

Fig 6:



Source: India's annual regional distribution of children born with congenital heart disease

Fig 7:



Source Comparing the number of babies born with severe cardiac condition to the regional distribution of those undergoing surgery

It is discovered that among the data offered by several Indian centers, there is a contradiction that a large number of centers are situated in areas where the prevalence of CHD is lower. The southern and western states of India have performed substantially better when taking the crucial CHD into account. compared to other areas (Fig. 6).States in India including Madhya Pradesh, Bihar, Jharkhand, and Uttar Pradesh are likely to have significantly higher rates of CHD than the other states. In India's central and eastern areas, the number of children born is steadily increasing. These days, pediatric cardiac care centers are located in various recently opened government institutions (AIIMS). These institutions currently do less congenital heart procedures, particularly for newborns and babies.

According to Poiseuille's law, the velocity depends on the radius of the tube in which blood is a not a Newtonian fluid for which the coefficient of viscosity μ is constant for viscous fluids. A simple model for non-Newtonian behaviour is the power law model given by $\beta = \mu e^{n-1} e$, where μe^{n-1} is effective viscosity coefficient. If the fluid is pseudo-plastic power fluid if n < 1. In the event that n = 1, the fluid is Newtonian and the fluid is dilatant if n is greater than 1.In actuality, the majority of biological fluids are non-Newtonian.

Formulation of the model and its solution:

Blood is delivered to the heart by arteries and veins. Except for pulmonary blood vessels, arteries carry oxygenated blood, and veins carry deoxygenated blood. The thick walls of arteries are composed of muscle tissue. Veins have thinner walls and need valves to keep blood flowing. Despite being blood vessels that transport blood from the heart to the body's other organs, arteries and veins are not the same. Arteries carry oxygen-rich blood out from the heart, whereas veins return blood with low oxygen content to the heart.. Arteries have a tight, cylindrical shape and are thick and muscular. Because they are thinner and less elastic, veins may seem distorted or collapsed. Veins are a component of a low-pressure system, whereas arteries can tolerate the high pressure of blood flow. Particularly in the arms and legs, veins' valves enable blood return to the heart and defy gravity. Although arteries don't convey a lot of blood, veins contain the majority of the body's blood. Compared to veins, arteries contain more oxygen and less carbon dioxide. Any change to the blood vessels or their characteristics might change blood flow and cause anything from little discomfort to death. Blood arteries are part of the circulatory system, which transports blood and nutrients from plasma to the body's tissues **[16].**The three primary types of blood vessels are capillaries, arteries, and veins.

Assuming blood to behave like a Newtonian viscous in compressible fluidwhose equation for

the unsteady flow of blood in a circular tube is $\rho\frac{\partial v}{\partial t} = A + \frac{\mu}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v}{\partial r}\right)$ ...(1)

Where v is the velocity of blood flow in artery, ρ is density of blood throughout the flow to be constant. μ is coefficient of viscosity of the blood, r is radius of blood vessel and A is constant due to pressure gradient associated boundary conditions are provided by

$v = 0$ at $r = R, v = 0$ at $t =$ 0 and v is finite $at\ r = 0$, where R resistance of blood vessel (caused by friction between the blood in the vessel wall).

Let equation (1) transform by using some boundary conditions such as

$\alpha = \mu\frac{v}{AR^2}, \beta = \frac{r}{R}, \omega = \frac{\gamma t}{R^2}$ (where, $\gamma = \frac{\mu}{\rho}$)

Now $\frac{\partial\alpha}{\partial\beta} = \mu\frac{1}{AR^2}\frac{\partial v}{\partial\beta} = \mu\frac{1}{AR^2}\frac{\partial v}{\partial t}\frac{\partial t}{\partial\beta} = \frac{v}{AR^2}\frac{\partial v}{\partial t}\frac{R^2}{\vartheta} = \frac{\mu}{A\vartheta}\frac{\partial v}{\partial t}$

Hence $\frac{\partial v}{\partial t} = \frac{A\vartheta}{\mu}\frac{\partial\alpha}{\partial\beta}$ and $\frac{\partial v}{\partial r} = \frac{\partial}{\partial r}\left(\frac{AR^2}{\mu}\alpha\right) = \frac{AR^2}{\mu}\frac{\partial\alpha}{\partial r}$

$$= \frac{AR^2}{\mu}\frac{\partial\alpha}{\partial\omega}.\frac{\partial\omega}{\partial r} = \frac{AR^2}{\mu}\frac{\partial\alpha}{\partial\omega}.\frac{1}{R} = \frac{AR}{\mu}\frac{\partial\alpha}{\partial\omega}$$

$$\therefore r\frac{\partial v}{\partial r} = \omega R.\frac{AR}{\mu}\frac{\partial\alpha}{\partial\omega} = \frac{AR^2}{\mu}\left(\varepsilon\frac{\partial\alpha}{\partial\omega}\right)$$

Thus from equation (1)

$$\rho\frac{A\vartheta}{\mu}\frac{\partial\alpha}{\partial\beta} = A + \frac{\mu}{\omega R}.\frac{AR}{\mu}\frac{\partial}{\partial\omega}\left(\omega\frac{\partial\alpha}{\partial\omega}\right)$$

$\therefore \frac{\partial\alpha}{\partial\beta} = 1 + \frac{1}{\omega}\frac{\partial}{\partial\omega}\left(\omega\frac{\partial\alpha}{\partial\omega}\right)$ ...(2)

With $\alpha = 0$ at $\beta = 0, \alpha = 0$, at $\omega = 1$ and α is finite at $\omega = 0$

For steady state, we have $\frac{\partial\alpha}{\partial\beta} = 0$

$$\therefore \frac{\partial}{\partial\omega}\left(\omega\frac{\partial\alpha}{\partial\omega}\right) = -\omega$$

$$\int\partial\left(\omega\frac{\partial\alpha}{\partial\omega}\right) = -\int\omega\,\partial\omega$$

Or $\omega\frac{\partial\alpha}{\partial\omega} = -\frac{1}{2}\omega^2 + g(\beta)$, where $g(\beta)$ is a constant of integration.

Or $\frac{\partial\alpha}{\partial\omega} = -\frac{1}{2}\omega + \frac{1}{\omega}g(\beta)$

Or $\alpha = -\omega^2 + g(\beta)\log\omega + g'(\beta)$, where $g(\beta)\&g'(\beta)$ are arbitrary constants

Using the condition α is finite at $\omega = 0$, so that $g(\beta) = 0$

And if $\alpha = 0$ at $\beta = 0$, $\alpha = 0$, at $\omega = 1$,, so that $g(\beta) = 1$

So, from equation (2), we have $\alpha = 1 - \omega^2$

Or $\emptyset_\infty(\omega) = 1 - \omega^2$

Now consider the transient dimensional velocity as:

$$\alpha_T(\omega,\beta) = \alpha_\infty(\omega) - \alpha(\omega,\beta)$$

Or $\alpha(\omega,\beta) = 1 - \omega^2 - \alpha_t(\omega,\beta)$... (3)

$\therefore \frac{\partial\alpha}{\partial\beta} = -\frac{\partial\alpha_t}{\partial\beta}$, $\frac{\partial\alpha}{\partial\omega} = -2\omega - \frac{\partial\alpha_t}{\partial\omega}\&\omega\frac{\partial\alpha}{\partial\beta} = -2\omega^2 - \omega\frac{\partial\alpha_t}{\partial\omega}$

$$\therefore \frac{\partial}{\partial\omega}\left(\omega\frac{\partial\alpha}{\partial\omega}\right) = -4\omega - \frac{\partial}{\partial\omega}\left(\omega\frac{\partial\alpha_t}{\partial\omega}\right)$$

So equation (2) becomes

$$-\frac{\partial\alpha_t}{\partial\beta} = 1 + \frac{1}{\omega}\left\{-\omega - \frac{\partial}{\partial\omega}\left(\omega\frac{\partial\alpha_t}{\partial\omega}\right)\right\}$$

Or $-\frac{\partial\alpha_t}{\partial\beta} = -\frac{1}{\omega}\frac{\partial}{\partial\omega}\left(\omega\frac{\partial\alpha_t}{\partial\omega}\right)$

Or $\frac{\partial\alpha_t}{\partial\beta} = \frac{1}{\omega}\frac{\partial}{\partial\omega}\left(\omega\frac{\partial\alpha_t}{\partial\omega}\right)$ ...(4)

With condition

$\alpha_t(\omega,0) = 1 - \omega^2, \alpha_t(1,\beta) =$ 0 $\&\alpha_t$ is finite at $\omega = 0$ ... (5)

Solution of eq (4) we can get by assuming-

$$\alpha_t = R(\omega)S(\beta)$$

$\therefore \frac{\partial\alpha_t}{\partial\beta} = R\frac{dS}{d\beta}\&\frac{\partial\alpha_t}{\partial\beta} = S\frac{dR}{d\omega}$

And $\frac{\partial}{\partial\omega}\left(\omega\frac{\partial\alpha_t}{\partial\omega}\right) = \frac{\partial}{\partial\omega}\left(\omega S\frac{\partial R}{\partial\omega}\right) = S(R'(\omega) + \omega R''(\omega))$

So from equation (4), $R\frac{dS}{d\beta} = \frac{1}{\omega}S(R'(\omega) + \omega R''(\omega))$

Or $\frac{1}{S}\frac{dS}{d\beta} = \frac{1}{R}\left(R''(\omega) + \frac{1}{\omega}R'(\omega)\right)$

Or $\frac{1}{S}\frac{dS}{d\beta} = \frac{1}{R}\left(R''(\omega) + \frac{1}{\omega}R'(\omega)\right) = -p_n^2$ (Assume)

If $\frac{1}{S}\frac{dS}{d\beta} = -p_n^2$ ... (6) and If $\frac{1}{R}\left(R''(\omega) + \frac{1}{\omega}R'(\omega)\right) = -p_n^2$ ...(7)

From eq (7) $S = M_n e^{-p_n^2 \beta}$, where $M_n$is constant of integration.

From eq (7),we have $\left(R''(\omega) + \frac{1}{\omega} R'(\omega)\right) + p_n^2 R = 0$ …(8)

To solve equation (8), it's a Bessel's Diff Equation its solution is $J_0(p_n \omega)$ Bessels function of zero order

So, solution of equation (4) is

$\alpha_t(\omega, \beta) = \sum_{n=1}^{\infty} M_n J_0(p_n \omega) e^{-p_n^2 \beta}$ …(9)

Using condition in equation (5)

$1 - \omega^2 = \sum_{n=1}^{\infty} M_n J_0(p_n \omega)$ …(10)

And $M_n = \frac{2}{p_n^3 J_1(p_n)}$ …(11)

$\therefore \alpha_t(\omega, \beta) = 2 \sum_{n=1}^{\infty} \frac{J_0(p_n \omega)}{p_n^3 J_1(p_n)} e^{-p_n^2 \beta}$ …(12)

Using equation (12) in equation (3), we have

$\alpha(\omega, \beta) = 1 - \omega^2 - 2 \sum_{n=1}^{\infty} \frac{J_0(p_n \omega)}{p_n^3 J_1(p_n)} e^{-p_n^2 \beta}$ …(13)

$\alpha = \mu \frac{v}{AR^2}$, $\omega = \frac{r}{R}$,$\beta = \frac{\vartheta t}{R^2}$

So $v(r, t) = \frac{AR^2}{\mu} \left[\left(1 - \frac{r^2}{R^2}\right) - 2 \sum_{n=1}^{\infty} \frac{J_0(p_n \omega / R)}{p_n^3 J_1(p_n)} e^{-\frac{\alpha p_n^2 \beta}{R}} \right]$

This is required velocity of flow of blood in a circular tube of radius r and R the resistance of blood vessel at any time t.

Result ad Discussion:

Now we analyse the behaviour of velocity of blood flow in blood vessels i.e; arteries which effect of heart attack in human

(i) If resistance due to blood flow is greater than the radius of blood vessels then the blood pressure will be high, it may be the arteries are blockage with an maximum rate of cholesterol and other substances. Because of this, the heart muscle can be quickly destroyed by a lack of blood flow.

.(ii) If resistance due to blood flow is equal to the radius of blood vessels, it means that the resistance due to blood flow will be equally distributed, so the possibility of block age in arteries may be continue to move toward loss.

(iii) If resistance of the blood flow is less than the radius of blood vessels, then it means that the resistance due to blood flow will be minimum and flow of blood in to the arteries will smoothly running and due to this effect of blood flow, the oxygen received in to the heart is smoothly functioning.

Thus we find that due to despite of the advancement of medicine and the technological era, many people are suffering from heart disease problems such as heart failure, heart attack, atrial fibrillation, etc. India is play an important and significant role which handling the CVDs among older and adults by implementing different public health programs but we are lacking with high rate of significant. So in front of us there is a major challenge to find control over it. It can be by the adaptation of healthy lifestyles, with the practice of regular exercise, healthy eating habits, smoking cessation, and moderation in alcohol consumption, which should be encouraged through community programs and partnerships with local organisations except the different government programs. Not only Older people but young people also should be participate in regular organize programs for CVD risk factors such as HT, diabetes, and high cholesterol to facilitate early detection. It should be mentioned that for heart patients, it is never too late to take action to stop a heart attack when experiencing heart pain. The unbalance and unhygienic diet, sedentary lifestyle, Lack of physical activity, high use of tobacco ,excess of stress and anxiety, Diabetes, Hypertension, Inadequate healthcare exposure is a risk factor for having a heart attack.

References:

[1]E .L. Olvera, B. D. Ballard, A. Jain, Cardiovascular Disease, in Stat Pearls (Internet),Treasure Island (FL),State Pear Publishing(2024).

[2]S. S. Martin, et al., Heart Disease and Stroke Statistics: A Report of US and Global Data From the American Heart Association, Vol.149:8 of AHAIASA (2024):e347-e913.

[3]A. Polak-Iwaniuk ,E. Harasim-Symbor , K. Gołaszewska, A. Chabowski, How Hypertension Affects Heart Metabolism. . Vol 10:435 of Front Physiol (2019)

[4 I. Julien, E. Hoffman, The global burden of congenital heart disease. Vol 24 of Cardiovascular J Africa (2013), 141-5.

[5] I. Julien, E. Hoffman, MD, FACC, Incidence of congenital heart disease: I.Postnatal incidence. Vol 39:12 of American College of Cardiology (1995)1890-1900.

[6]R. Gupta, S. Guptha S, K.K.Sharma, A. Gupta, P. Deedwania ,.Regional variations in cardiovascular risk factors in India: India heart watch. Vol4:4 of World J. Cardiol (20212) 112-120.

[7]P.M. Kearney,M.Whelton,K. Reynolds,P. Muntner, P.K. Whelton, J. He, Global burden of hypertension: analysis of worldwide data. Vol 365:9455 of Lancet (2005) 217-23. .

[**8]**H.Allayee, et al. COVID-19 Is a Coronary Artery Disease Risk Equivalent and Exhibits a Genetic Interaction With ABO Blood,(2024) Arteriosclerosis, Thrombosis, and Vascular Biology(2024)

[**9]**Jan.Bisma et al .Cardiovascular Diseases Among Indian Older Adults: A Comprehensive Review: (2024)

[10] A.S.Kumar,N. Sinha, Cardiovascular disease in India: a 360 degree overviewVol 76:1 of Medical Journal Armed Forces India. (2020) 1–3

[11]A. Kalra , A.P. Jose, P. Prabhakaran, A. Kumar,A Agrawal, A. Roy, B.Bhargava, N. Tandon D.Prabhakaran,The burgeoning cardio vascular disease epidemic in Indians–perspectives on contextual factors and potential solutions, Vol 12 of The Lancet Regional Health-Southeast Asia. (2023) 12, article 100156.

[12]A. Saxena, Congenital heart disease in India: a status report.Vol 72:7 ofIndian J Pediatr (2005)595-8.

[13]S. Ramakrishnan. Pediatric cardiology: Is India self-reliant?. , Vol 14:3 of Annals of pediatric cardiology(2021) 253–259.

[14] World Health Report 2023.

[15] H. Dolk , M. Loane , E. Garne, Garne E; European Surveillance of Congenital Anomalies (EUROCAT) Working Group. Congenital heart defects in Europe: prevalence and perinatal mortality, 2000 to 2005. Circulation, Vol 123:8 (2011) 841-9

[16]R. J. Levick, An introduction to cardiovascular physiology of London Boston: Butter worths. ISBN *(1991)*