



Mathematical Modeling of two Phase Human Pulmonary Mean Blood Flow in Arterioles during Lung Cancer

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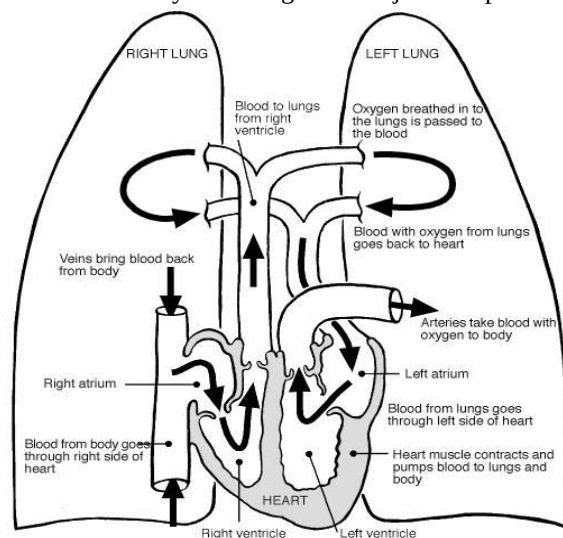
Abstract: Present paper envisage a model of two phased mean blood flow in human Pulmonary arterioles remote from the heart and proximate to the Lung, Keeping in view the nature of Pulmonary blood circulation in human body. The viscosity increases in the arterioles due to formation of rouleaux along axis of red blood cells. We have applied the Herschel Bulkley Non-Newtonian model in Bio- fluid mechanical setup with the help of clinical data in case of Lung Cancer for hemoglobin versus blood pressure. The overall presentation is in tensorial form and the solution technique adopted is analytical as well as numerical. The role of hematocrit is explicit in the determination of blood pressure in case of pulmonary disease Lung Cancer the graphical presentation for particular parametric value is much close to the clinical observation.

Keywords: Structure of the Lung, Hematocrit, Lung Cancer, Pulmonary Blood Flow, Herschel Bulkley Non-Newtonian model etc.

I. Introduction

A. Structure and function of the Lung:

The Human has two lungs they are paired organs in the chest the right lung has three lobes but the left lung has two lobes. It is smaller to accommodate to heart, whose position is below the left lung and takes up the space of the third lobes in the chest cavity. The lungs behave just like purification station for blood.

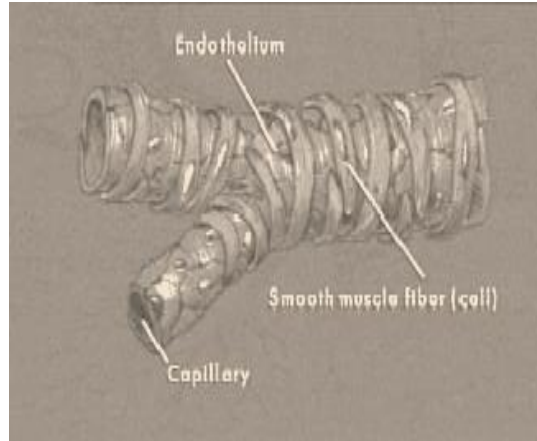


Normal blood flow of heart and lungs

The physiological aspects of the lung can be rather naturally grouped into a number of almost distinct sub-topics: gas exchange, neural control, mechanics, and non-respiratory functions related mostly to defense. Indeed, advanced treatises on the lung invariably partition the subject along these lines, and even the corresponding communities of scientists currently pushing forward the frontiers of knowledge in these various areas remain largely distinct. We are not going to cross these boundaries to any significant degree here, being almost exclusively concerned with lung mechanical function. Nevertheless, it must be remembered that all aspects of pulmonary physiology are vital to the lung's ability to function normally within a human to sustain life (Guyton and Hall).

B. Structure and Functions of the Pulmonary Arterioles:

Blood pumped by the heart through a series of vessels known as arteries, arterioles, capillaries, veins and venules, before returning to the heart. Arteries transport blood away from the heart and branch into smaller vessels, forming arterioles. Arterioles distribute blood to capillary beds, the sites of exchange with the body tissues. Capillaries lead back to small vessels known as venules that blood pump into the larger veins and eventually back to the heart (Browne Donna).



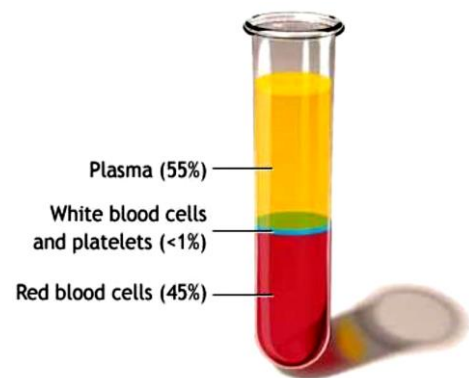
In general, arterioles are defined as the primary resistance vessels that enter an organ to distribute blood flow into capillary beds. These blood vessels vary significantly in diameter depending on species, vascular bed and state of contraction. Therefore, their main identifying feature is not size, but the fact that their wall consists of only one or two layers of smooth muscle. Arterioles are considered part of the resistance vasculature that provides in excess of 80% of the resistance to blood flow in the body. So, they are vital to the regulation of hemodynamics, contributing to the control of blood pressure and the regional distribution of blood (Luis A. and Martinez-Lemus, 2011).

We have envisage mathematical modeling with the help of two phase model we explain the blood flow in various arterioles in the human heart. But present work will focus on pulmonary circulatory system, and pulmonary circulatory system is a sub system of whole circulatory system. In previous work, is based on realistic the Herschel Bulkley non-Newtonian model, (Srivastava, Manoj and Trivedi *et al.*, 2012). On the basis of previous work in present study we achieve new findings which are discussed separately below.

C. Constitution of Blood:

Blood is concentrated suspension of several formed cellular elements, red blood cells (RBCs or erythrocytes), white blood cells (WBCs or leukocytes) and platelets (thrombocytes), in an aqueous polymeric and ionic solution, the plasma, composed of 93% water and 3% particles.

Plasma's central physiological function is to transport these dissolved substance, nutrients, wastes and the formed cellular elements throughout the circulatory system. Normal erythrocytes are biconcave discs with a mean diameter of 6 to 8 μm and a maximal thickness of 1.9 μm . The average volume of an erythrocyte is 90 μm . their number per cubic millimeter of blood is approximately 5 to 6 $\times 10^6$ and they represent approximately 40 to 45% by volume of the normal human blood and more than 99% of all blood cells. The first percentage is called hematocrit. Thrombocytes are a vital component of the blood clotting mechanism. The total volume concentration of leukocytes and thrombocytes is only about 1% (N. Bessonov *et al.*, 2016). Then we have considered only two phases of blood. Which is one of red blood cells and other phase is plasma.



D. Description of Lung Cancer:

Lung cancer is the second most common cancer and the leading cause of cancer related mortality in both men and women. Each year more people die of lung cancer than of colon, breast, and prostate cancers combined. It is widely accepted that tumor metastasis is a formidable barrier to effective treatment of lung cancer. The bone is one of the frequent metastatic sites for lung cancer occurring in a large number of patients. Bone metastases can cause a wide range of symptoms that could impair quality of life of lung cancer patients and shorten their survival. We strongly believe that molecular targets (tumor-related and bone microenvironment based) that have been implicated in lung cancer bone metastases hold great promise in lung cancer therapeutics (Moses, *et al.*, 2014). Lung cancer cells can spread by breaking away from a lung tumor. They can travel through blood vessels or

lymph vesselsto reach other parts of the body. After spreading, cancer cells may attach to other tissues and grow to form new tumors that may damage those tissues.

When lung cancer spreads from its original place to another part of the body, the new tumor has the same kind of abnormal cells and the same name as the primary (original) tumor. For example, if lung cancer spreads to the bones, the cancer cells in the bones are actually lung cancer cells. The disease is metastaticlung cancer, not bone cancer. For that reason, it is treated as lung cancer, not bone cancer (National Cancer Institute – Lung Cancer).

Small cellthe cells of small cell lung cancer look small under a microscope. About 1 of every 8 people with lung cancer has small cell lung cancer. And the cells of non-small cell lung cancer are larger than the cells of small cell lung cancer. Most (about 7 of every 8) people diagnosed with lung cancer have non-small cell lung cancer. It doesn't grow and spread as fast as small cell lung cancer, and it's treated differently (National Cancer Institute – Lung cancer).

II. Real Model

A. Choice of frame of reference:

We have to choice a frame of reference for mathematical modeling of the state of a moving blood· keeping in view the difficulty and generality of the problem of blood flow, we select generalized three-dimensional orthogonal curvilinear co-ordinate system, briefly prescribed as E3, called as 3-dim Euclidean space, We interpret the quantities related to blood flow in tensorial form which is comparatively more realistic, The biophysical laws thus expressed fully hold good in any co-ordinate system , which is compulsion for the truthfulness of the law (Mishra *et al.*, 1965). Now , let the co-ordinate axes be OX_i , O denotesorigin and superscript $i= 1,2,3$ let X_i be the co-ordinates of any point P in space, The mathematical description of the state if a moving blood is affected by means of functions which give the distribution of the blood velocity $v_k = v_k(X_i , t)$, $k= 1,2,3$ and of any two thermodynamic quantities pertaining to the blood, for instance the pressure $p = p(X_i , t)$ and the density $\rho = \rho(X_i , t)$, As is well known, all the thermodynamic quantities are determined by the values of any two of them, together with the equate of state, Hence, if we are given five quantities, namely the three components of velocity v_k , the pressure p and the density ρ , the state of moving blood is completely determined· All these quantities are , in general , functions of the co-ordinates X_i , $i=1,2,3$ and of the time t , We emphasize that $V_k(X_i , t)$ is the velocity of the blood at a given point X_i in space and at a given t , *ie* it refers to fixed points in space and not to fixed particles of the blood; in the course of time , the latter move about in space , The same remarks apply to p and ρ Blood is a mixed fluid.

The first phase is red blood cells, and other phase is plasma, while the other phaseis that of blood cells. The blood cells are enclosed with a semi-permeable membrane whose density is greater than that of plasma, these blood cells are uniformly distributed in plasma, Thus blood can be considered as a homogeneous mixture of two-phases (Sherman *et al.* 1989).

B. Choice of parameters:

Because blood is the Non- Newtonian fluids, then using this constitutive equation for fluids.

$$\tau = \eta e^n$$

If $n = 1$ then the nature of fluid is Newtonian and if $n \neq 1$ then the nature of fluid is Non-Newtonian fluids. Where, τ is denoted by stress, e is denoted by strain rate and n is denoted by the parameter, these equation uses equation of motion. In present study there are five parameter are used but three parameter components of velocity are frequently used namely velocity, pressure P and density ρ . (Upadhyay, 2000).

C. Choice of constitutive equation:

We have using in two phase blood flow through arterioles and whose constitutive equation is as follows-

$$T' = \eta_m e^n + T_p (T' \geq T_p) \text{ where, } T_p \text{ is the yield stress.}$$

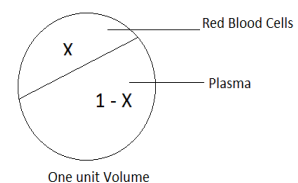
When strain rate $e = 0$ ($T' < T_p$) a core region is formed which flows just like a plug (Upadhyay, 2000).

D. Constitution of two phase blood volume:

They are already conceder two-phases in blood(SrivastavaManoj and Trivedi *et al.*, 2012). The flow of blood is affected by the presence of blood cells. This effect is directly proportional to the volume occupied by blood cells.

Let the volume portion covered by blood cells in unit volume be X , X is replaced by $H/100$, where H is the Hematocrit the volume percentage of blood cells. Then the volume portion covered by the plasma will be $(1-X)$. If mass ratio of cells to plasma is r then clearly: $r = \frac{X\rho_c}{(1-X)\rho_p}$.

Where ρ_c and ρ_p are densities of blood cells and plasma respectively. Usually this mass ratio is not a constant. Even then this may be supposed to constant in present context.



III. Mathematical Model / Formulation

We have recommended that blood flow in vessels is a peristaltic transport system because they thought blood is having two layers of fluid while in the peripheral reasons of vessels blood flow is a Newtonian phenomenon. Blood is in the liquid form and it is non-Newtonian. Though blood is not an ideal fluid, even to develop the equation of motion. (Singh and Pandey, 1986), we start with a model of ideal fluid. The second important principle of fluid dynamics is that of conservation of momentum. The equation of motion is based on this principle. According to this principle, the total momentum of any fluid system is conserved in absence of external force.

$$\frac{dp}{dt} + P - F_{v(viscosity)} = 0 \text{ (External Force)}$$

The blood can be considered as homogeneous mixtures of two phases. We derive the fundamental equation of continuity, which is a mathematical expression of principle of conservation of matter.

A. Equation of Continuity:

If mass ratio of cells to plasma is r then clearly:

$$r = \frac{X\rho_c}{(1-X)\rho_p} \quad (1)$$

Where ρ_c and ρ_p are densities of blood cells and plasma respectively. Usually this mass ratio is not a constant. Even then this may be supposed to constant in present context.

The both phase of blood, i.e. blood cells and plasma move with the common velocity. Campbell and Pitcher have presented a model for this situation. Giving to this model, we consider the two phase of blood separately. The principles of conservation of mass in pulmonary circulatory system, equation of continuity for two phases are following as

$$\frac{\partial(X\rho_c)}{\partial t} + (X\rho_c V^i)_{,i} = 0 \quad (2)$$

$$\frac{\partial(1-X)\rho_p}{\partial t} + (1-X)\rho_p V^i_{,i} = 0 \quad (3)$$

Where V is the common velocity of two phase blood cells and plasma. If we define the uniform density of blood ρ_m as follows:

$$\frac{1+r}{\rho_m} = \frac{r}{\rho_c} + \frac{1}{\rho_p} \quad (4)$$

Then equation (2) and (3) can be combined together as:

$$\frac{\partial\rho_m}{\partial t} + (\rho_m V^i)_{,i} = 0 \quad (5)$$

Equation of motion for blood-flow:

The hydro dynamical pressure P between the two phases of blood can be supposed to be uniform because the both phases i.e. blood cells and plasma is always in equilibrium state in blood. Taking viscosity coefficient of blood cells to be η_c and applying the principle of conservation of momentum in pulmonary circulatory system, we get the equation of motion for the phase of blood cells as follows:

$$X\rho_c \frac{\partial V^i}{\partial t} + (X\rho_c V^j) V^i_{,j} = -X\rho_c g^{ij} + X\eta_c (g^{jk} V^i_{,k})_{,j} \quad (6)$$

Similarly, taking the viscosity coefficients of plasma to be equation of motion for plasma will be as follows-

$$(1-X)\rho_p \frac{\partial V^i}{\partial t} + \{(1-X)\rho_p V^j\} V^i_{,j} = -(1-X)\rho_p g^{ij} + (1-X)\eta_c (g^{jk} V^i_{,k})_{,j} \quad (7)$$

Now adding equation (6) and (7) and using relation (4), the equation of motion for blood flow with the both phases will be as follows-

$$\rho_m \frac{\partial V^i}{\partial t} + (\rho_m V^j) V^i_{,j} = -P_{,j} + \eta_m (g^{jk} V^i_{,k})_{,j} \quad (8)$$

Where $\eta_m = X\eta_c + (1-X)\eta_p$ are the viscosity coefficients of blood as a mixture of two phases. In this situation, the blood cell line up on the axis to build up rolex. Hence a yield stress is produced. Though this yield stress is very small, even then the viscosity of blood is increased nearly ten times. The Herschel Bulkley law holds good on the two phase blood flow through arterioles and whose constitutive equation is as follows- $T' = \eta_m e^n + T_p$ ($T' \geq T_p$). where, T_p is the yield stress.

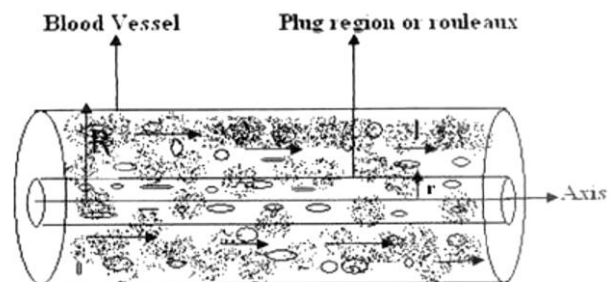


Fig (3): Herschel Bulkley blood flow

When strain rate $e = 0$ ($T' < T_p$) a core region is formed which flows just like a plug. Let the radius of the plug be r_p . The stress action on the surface of plug will be T_p . Equating the forces acting on the plug, we get,

Whose generalizes from will be as follows-

$$T^{ij} = -Pg^{ij} + T_e^{ij} \quad (9)$$

Where $T^{ij} = \eta_m (e^{ij})^n$ while $e^{ij} = (g^{ik}V_{,k}^i + g^{ik}V_{,k}^j)$

Where the symbols have their usual meanings.

Now we consider the basic equation for Herschel-Bulkley flow as follows.

Equation of Continuity-

$$\frac{1}{\sqrt{g} \sqrt{(gV^i)_{,i}}} = 0 \quad (10)$$

Equation of Motion-

$$\rho_m \frac{\partial V^i}{\partial t} + \rho_m V^j V^i_{,j} = -T^{ij} e_{,j}$$

Where all the symbols have their usual meaning.

IV. Analysis:

Since, the blood vessels are cylindrical; the above governing equations have to be transformed into cylindrical co-ordinates. As we know earlier: $X^1 = r, X^2 = \theta, X^3 = z$.

Matrix of metric tensor in cylindrical co-ordinates is as follows-

$$[g^{ij}] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & r^2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

While matrix of conjugate metric tensor is as follows-

$$[g_{ij}] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1/r^2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Where the Christoffel's symbols of 2^{nd} kind as follows-

$$\left\{ \begin{matrix} 1 \\ 2 \end{matrix} \begin{matrix} 1 \\ 2 \end{matrix} \right\} = -r, \left\{ \begin{matrix} 1 \\ 2 \end{matrix} \begin{matrix} 1 \\ 2 \end{matrix} \right\} = \left\{ \begin{matrix} 1 \\ 2 \end{matrix} \begin{matrix} 1 \\ 2 \end{matrix} \right\} = \frac{1}{r} \text{ remaining others are zero.}$$

Relation between contra variant and physical components of velocity of blood flow will be as follows-

$\sqrt{g^{11}}v^1 = v_r \Rightarrow v_r = v^1, \sqrt{g^{22}}v^2 = v_\theta \Rightarrow v_\theta = rv^2, \sqrt{g^{33}}v^3 = v_z \Rightarrow v_z = v^3$, again the physical components of $p_j g^{ij}$ are $\sqrt{g_{ij}}p_j g^{ij}$

Now, equation 9 and 10 are transformed into cylindrical from so as to solve as power law to get

Equation of continuity:

$$\frac{\partial V}{\partial z} = 0$$

The equation of motion-

r-component: $-\frac{\partial p}{\partial z} = 0, \theta$ - component: $0 = 0$

z-component: $0 = -\frac{\partial p}{\partial z} + \frac{\eta_m}{r} \left[r \left(\frac{\partial v_z}{\partial r} \right)^n \right]$

Here, this fact has been taken in view that the blood flow the axially symmetric in arteries concerned, i.e. $V_\theta = 0$ and V_r, V_z and $p = p(z)$ and

$$0 = -\frac{\partial p}{\partial z} + \frac{\eta_m}{r} \left[r \left(\frac{\partial v_z}{\partial r} \right)^n \right] \quad (11)$$

Since, pressure gradient $-\frac{dp}{dz} = P$

$r \left(\frac{dv}{dz} \right)^n = -\frac{Pr^2}{2\eta_m} + A$, we apply boundary condition at $r = 0, V = V_0$ than $A = 0$.

$\Rightarrow -\frac{dv}{dr} = \left(\frac{Pr}{2\eta_m} \right)^{\frac{1}{n}}$ Replace from $r - r_p$

$$-\frac{dv}{dr} = \left(\frac{\frac{1}{2}Pr - \frac{1}{2}Pr}{\eta_m} \right)^{\frac{1}{n}} \Rightarrow \frac{dv}{dr} = -\left(\frac{P}{2\eta_m} \right)^{\frac{1}{n}} (r - r_p)^{\frac{1}{n}} \quad (12)$$

Integrating above equation (12) under the no slip boundary condition $V = 0$ at $r = R$ so we get:

$$v = \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{n}{n+1} \left[(R - r_p)^{\frac{1}{n}+1} - (r - r_p)^{\frac{1}{n}+1} \right] \quad (13)$$

This is the formula for velocity of blood flow in arterioles.

Putting $r = r_p$ to get the velocity v_p of plug flow as follows:

$$v_p = \frac{n}{n+1} \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} (R - r_p)^{\frac{1}{n}+1} \quad (14)$$

Where the value of r_p is taken from (7).

V. Result and Discussion

Examination: Hematocrit v/s blood pressure in during Lung Cancer patient.

Patient name: Smt.Sama Parween **Age :**38 years old

Diagnosis: Lung cancer (Pulmonary disease)

Date	HB(Hemoglobin)	Hematocrit ($3 \times HB$)	BP (Blood Pressure)	Pressure drop $\left(\frac{\frac{S+D}{2} + D}{3} - \left(\frac{S+D}{2}\right)\right)$
02/03/2011	12.9	38.7	100/60	-33.333333
08/11/2011	12.4	37.2	160/100	-53.333333
09/06/2012	11.6	34.8	140/90	-46.666667
16/10/2013	11.0	33.0	130/90	-43.333333
31/10/2014	11.2	33.6	120/100	-40.00

The flow two phased blood flow in arterioles is-

$$\begin{aligned}
 Q &= \int_0^{r_p} 2\pi r v_p + \int_{r_p}^R 2\pi r v dr \\
 &= \int_0^{r_p} 2\pi r \frac{n}{n+1} \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} (R - r_p)^{\frac{1}{n}+1} dr + \int_0^{r_p} 2\pi r \frac{n}{n+1} \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \left[(R - r_p)^{\frac{1}{n}+1} - (R - r_p)^{\frac{1}{n}+1} \right] dr \\
 \text{Using (12) and (14), we get} \\
 Q &= \frac{2\pi n}{(n+1)} \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} (R - r_p)^{\frac{1}{n}+1} \left[\frac{r^2}{2} \right]_0^{r_p} + \frac{2\pi n}{(n+1)} \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \left[\frac{r^2}{2} (R - r_p)^{\frac{1}{n}+1} - \frac{r(r - r_p)^{\frac{1}{n}}}{\frac{1}{n}+1} + \frac{(r - r_p)^{\frac{1}{n}+3}}{\left(\frac{1}{n}+1\right)\left(\frac{1}{n}+3\right)} \right]_0^{r_p} \\
 Q &= \frac{2\pi n}{(n+1)} \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \left[r_p^2 (R - r_p)^{\frac{1}{n}+1} + R^2 (R - r_p)^{\frac{1}{n}+1} - \frac{2R(R - r_p)^{\frac{1}{n}+2}}{\left(\frac{1}{n}+2\right)} + \frac{2R(R - r_p)^{\frac{1}{n}+3}}{\left(\frac{1}{n}+2\right)\left(\frac{1}{n}+3\right)} - r_p^2 (R - r_p)^{\frac{1}{n}+1} \right] \\
 Q &= \frac{\pi n}{(n+1)} \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} R^{\frac{1}{n}+3} \left[\frac{r_p^2}{r^2} \left(1 - \frac{r_p^2}{R}\right)^{\frac{1}{n}+1} + \left(1 + \frac{r_p}{R}\right)^{\frac{1}{n}+1} \left(1 - \frac{r_p}{R}\right)^{\frac{1}{n}+2} - \frac{2\left(1 - \frac{r_p}{R}\right)^{\frac{1}{n}+2}}{\left(\frac{1}{n}+2\right)} + \frac{2\left(1 - \frac{r_p}{R}\right)^{\frac{1}{n}+3}}{\left(\frac{1}{n}+2\right)\left(\frac{1}{n}+3\right)} \right] \dots (15)
 \end{aligned}$$

P = Pressure gradient, v = Viscosity of mixture (Blood), n = Parameter

Now, we have, $Q = 425 \frac{\text{ml}}{\text{min}}$, $Q = 0.00708333 \text{ m}^3/\text{second}$ and $R = 1$, $r_p = \frac{1}{3}$,

According to Gustafson, Daniel R. (1980)

$$\eta_p = 0.0013 \text{ pascal second}$$

According to Glenn Elert (2010)

$$\eta_m = 0.027 \text{ pascal second and } H = 38.7$$

Pressure drop $(P_f - P_i) = 4437.7333 \text{ Pascal second}$ and Pulmonary arterioles length = 0.05 m^3 (5 cm)

By using relation $\eta_m = \eta_c X + \eta_p (1 - X)$, Where $X = \frac{H}{100}$, and we get η_c

$$\eta_m = \eta_c X + \eta_p (1 - X)$$

$$0.0271 = \eta_c(38.7) + 0.0013(0.613) \Rightarrow \eta_c = 0.06796667 \text{ Pascal second}$$

Again using this relation and change in to the hematocrit-

$$\eta_m = \eta_c X + \eta_p (1 - X) \Rightarrow \eta_m = 0.0006796667H + 0.0007969$$

Now substituting the values of r_p and R in Equation (15)-

$$Q = \frac{\pi n}{(n+1)} \left(\frac{P}{2\eta_m} \right)^{\frac{1}{n}} R^{\frac{1}{n}+3} \left[\frac{r_p^2}{r^2} \left(1 - \frac{r_p}{R} \right)^{\frac{1}{n}+1} + \left(1 + \frac{r_p}{R} \right)^{\frac{1}{n}+1} \left(1 - \frac{r_p}{R} \right)^{\frac{1}{n}+2} - \frac{2 \left(1 - \frac{r_p}{R} \right)^{\frac{1}{n}+2}}{\left(\frac{1}{n}+2 \right)} + \frac{2 \left(1 - \frac{r_p}{R} \right)^{\frac{1}{n}+3}}{\left(\frac{1}{n}+2 \right) \left(\frac{1}{n}+3 \right)} \right]$$

And we get equation-

$$Q = \pi \left(\frac{2P}{6\eta_m} \right)^{\frac{1}{n}} \left(\frac{2}{27} \right) \left[\frac{26n^3 + 33n^2 + 9n}{6n^3 + 11n^2 + 6n + 1} \right]$$

$$\text{Or, } \frac{27 \times Q}{2\pi} = \left(\frac{P}{3\eta_m} \right)^{\frac{1}{n}} \left[\frac{26n^3 + 33n^2 + 9n}{6n^3 + 11n^2 + 6n + 1} \right] \text{ and Let } A = \left[\frac{26n^3 + 33n^2 + 9n}{6n^3 + 11n^2 + 6n + 1} \right]$$

$$\Rightarrow \frac{P}{3\eta_m} = \left(\frac{27 \times Q}{2\pi A} \right)^n \Rightarrow P = \left(\frac{27 \times Q}{2\pi A} \right)^n \cdot 3\eta_m$$

$$P = - \frac{dp}{dz} \Rightarrow -dp = Pdz$$

And limit from the pressure from Z_f to Z_i then-

$$\int_{P_f}^{P_i} dP = - \int_{Z_f}^{Z_i} \left(\frac{27 \times Q}{2\pi A} \right)^n \cdot 3\eta_m dz$$

Where $P_f - P_i$ = pressure drop and $Z_f - Z_i$ = pulmonary artriols length.

$$P_f - P_i = \left(\frac{27 \times Q}{2\pi A} \right)^n \cdot 3\eta_m \cdot (Z_f - Z_i)$$

$$\text{Or, } \frac{27 \times Q}{2\pi A} = \left(\frac{P_f - P_i}{(Z_f - Z_i) 3\eta_m} \right)^{1/n}$$

$$\frac{27 \times Q}{2\pi} = \left[\frac{26n^3 + 33n^2 + 9n}{6n^3 + 11n^2 + 6n + 1} \right] \left(\frac{P_f - P_i}{(Z_f - Z_i) 3\eta_m} \right)^{1/n}$$

Substituting the value of Q , η_m , $(P_f - P_i)$ and $(Z_f - Z_i)$ and solve by numerical methods

$$\frac{27 \times 0.0070833}{6.28} = \left[\frac{26n^3 + 33n^2 + 9n}{6n^3 + 11n^2 + 6n + 1} \right] \left(\frac{4437.7333}{0.05 \times 0.081} \right)^{1/n}$$

$$0.03045669 = \left[\frac{26n^3 + 33n^2 + 9n}{6n^3 + 11n^2 + 6n + 1} \right] (1095736.62)^{1/n} \text{ And we get } n = -2.902$$

Now again using equation

$$P_f - P_i = \left(\frac{27 \times Q}{2\pi A} \right)^n \cdot 3\eta_m \cdot (Z_f - Z_i) \Rightarrow \Delta P = \left(\frac{27 \times Q}{2\pi A} \right)^n \cdot 3\eta_m \cdot (Z_f - Z_i)$$

$$= \left(\frac{27 \times 0.007084}{6.28 \times 3.674254927} \right)^{-2.902} \times 3\eta_m \times (0.05) \Rightarrow (1097675.95) \times (0.05) \times 3\eta_m$$

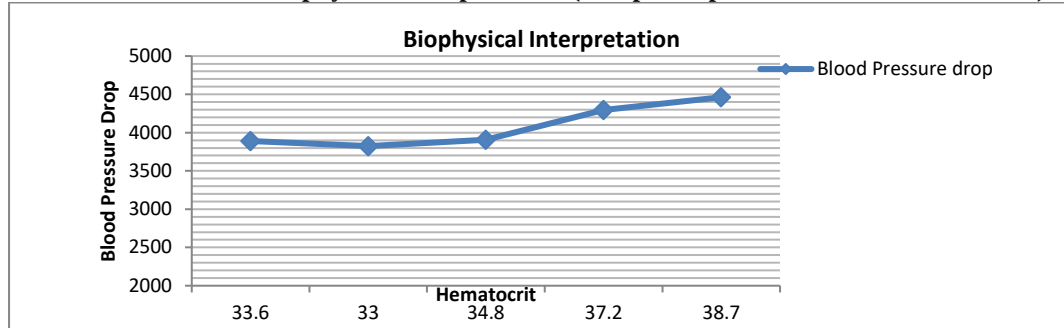
$$= 164651.3925(0.0006796667H + 0.0007969) \Rightarrow 111.908069H + 131.210695$$

$$\Delta P = 111.908069H + 131.210695$$

Table for Hemoglobin v/s Pressure drop

H (Hematocrit)	38.7	37.2	34.8	33.0	33.6
BP(Blood Pressure drop)	4462.05296	4294.19086	3907.6115	3824.17698	3891.32182

VI. Biophysical Interpretation (Graphical presentation of Clinical Data)



VII. Conclusion:

A simple investigation of the graph 33.6 to 37.2 down convex and 37.2 to above graph upper convex between blood pressure drop and hematocrit in suffering lung cancer patient and confirmations that when hematocrit increase then blood pressure drop also increased. That is hematocrit inversely proportional to blood pressure drop.

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