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Change of Blood Pressure Due to Volume Changes

تغير ضغط الدم معتغير حجمه

A thesis submitted in partial fulfillment of the requirements for MSc. degree in Physics

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الآيه

قال تعالي

{اللَّهُ نُورُ السَّمَاوَاتِ وَالْأَرْضِ مَثَلُ نُورِهِ كَمِشْكَاةٍ فِيهَا

مِصْبَاحٌ الْمِصْبَاحُ فِي زُجَاجَةٍ الزُّجَاجَةُ كَأَنَّهَا كَوْكَبٌ

دُرِّيٌّ يُوقَدُ مِن شَجَرَةٍ مُّبَارَكَةٍ زَيْتُونَةٍ لَّا شَرْقِيَّةٍ وَلَا غَرْبِيَّةٍ

يَكَادُ زَيْتُهَا يُضِيءُ وَلَوْ لَمْ تَمْسَسْهُ نَارٌ نُّورٌ عَلَى نُورٍ

يَهْدِي اللَّهُ لِنُورِهِ مَن يَشَاءُ وَيَضْرِبُ اللَّهُ الْأَمْثَالَ

لِلنَّاسِ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ}

سورة النور

الآية 35

Dedication

I dedicate this work to my parents

To my friends &colleagues

To my sisters

Acknowledgment

I deeply thank Allah who gave me the power to perform this work. I would like to give a special thanks to **Prof Mubarak Dirar**, who has given me the support and confidence to do this research. I would also like to thank Department of physics college of science, graduate college and Sudan University of Science and Technology for enabling me to do this research at sust university thanks also extends to Dr. Iman, Dr. Abdalsakhi Suleiman Mohamed Hamid, Asia Hospital, and all how supported me with the information which has the greatest role to fulfill this research.

Abstract

In this work dextrose normal saline (DNS) infusion (500ml) with 8.3ml/sec was add to blood, it was found that the blood pressure decreases when increasing the infusion amount. This may be due to the fact that increasing infusion amount decreases blood density which in turn decrease blood pressure. This effect can be easily explained on the basis of continuity equation and Bernoulli's equation

مستخلص البحث

فى هذا البحث اضيف محلول السكر و الملح (500مل) الى الدم بمعدل سريان 8.3 مل/ث ووجد ان الضغط ينخفض تبعا لزيادة كمية المحلول في الدم . وقد يكون هذا مرده لحقيقة أن زيادة كمية المحلول تقلل كثافة الدم وهذا بدوره يقلل ضغط الدم . هذا التاثير يمكن تفسيره بسهولة على ضوء معادلة الاستمرار ومعادلة بيرنولي.

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Chapter One

Introduction

1.1 Fluid pressure

The term fluid is used for liquids and gases. Liquids and gases are characterized by physical parameters like temperature and pressure. The fluid pressure is the force exerted per unit area of the boundary surface [1]. Fluids are very important for human life .Most of human cell consists of 65% water .The blood of human is in the form of a fluid. Blood is the body's internal transportation system. Pumped by the heart, blood travels through a network of blood vessels, carrying nutrients (O_2, glucose) and hormones to the cells and removing waste products (CO_2 , urea) from the 10^{12} (100 trillion) cells of our bodies. The blood is very important for human life since it provides body with oxygen and energy. The blood circulation takes place under the effect of certain blood pressure. Blood moves through our circulation system because it is under pressure, caused by the contraction of the heart and by the muscles that surround our blood vessels. The measure of this force is blood pressure. Blood pressure will always be highest in the two main arteries, just outside the heart, but, because the pulmonary circulation is inaccessible, blood pressure is measured in the systemic circulation only, i.e. blood leaving the left ventricle only – normally in the upper arm this pressure should be in a certain range to deliver all organs with vital energy [2] this means that it is very important to study the factors affecting blood pressure to be in the permissible range.

1.2 Importance of Blood Pressure

The importance of the research is related to the risk of illness and death which are related to changes in blood pressure [3]. Hypertension is a major risk factor for stroke, myocardial infarction (heart attacks), heart failure, aneurysms of the arteries (aortic aneurysm), and peripheral arterial disease and is a cause of chronic kidney disease [4].

1.3 Research Problem

There are no intensive research concerning the physical factors affecting blood pressure like volume and viscosity .Specially the effect of adding fluids on blood pressure is not extensively studied.

1.4 Literature Review:

Evidence from epidemiological studies and experimental trial in animals and humans suggests that added sager may increase blood pressure [5].Study suggests sugar and a salt are bad for blood pressure. Consumption of salts raises blood pressure [6].

1.5 Outline of Research

The Outline of thesis is structured as follow: Chapter one is devoted for an introduction. Chapter two will be concerned with the law governing fluids. Chapter three is an introduction to the blood pressure. In chapter four the results, discussions and conclusions are presented.

Chapter two

Fluid laws

2.1 Introduction

This chapter is concerned with the basic laws of fluid. It includes relation between pressure, velocity, volume and viscosity.

2.2 Mass Conservation Equation

We consider the changes for a fluid that is moving through our domain. There is no accumulation or depletion of mass, so mass is conserved within the domain. Since the fluid is moving, defining the amount of mass gets a little tricky. Let's consider an amount of fluid that passes through point "a" of our domain in some amount of time t. If the fluid passes through an area A at velocity v, we can define the volume V to be:

$$V = Avt \tag{2.2.1}$$

A units check gives area x length/time x time = area x length = volume. Thus the mass at point "a" m_a is simply density ρ times the volume at "a".

$$m_a = (\rho AVt)_a \tag{2.2.2}$$

If we compare the flow through another point in the domain, point "b," for the same amount of time t, we find the mass at m_b to be the density times the velocity times the area times the time at "b":

$$m_b = (\rho AVt)_b \tag{2.2.3}$$

From the conservation of mass, these two masses are the same and since the times are the same, we can eliminate the time dependence.

$$(\rho AV)_a = (\rho AV)_b \tag{2.2.4}$$

Or

$$\rho AV = Constant \tag{2.2.5}$$

The conservation of mass gives us an easy way to determine the velocity of flow in a tube if the density is constant. If we can determine (or set) the velocity at some known area, the equation tells us the value of velocity for any other area. In our animation, the area of "b" is one half the area of "a." Therefore, the velocity at "b" must be twice the velocity at "a." If we desire a certain velocity in a tube, we can determine the area necessary to obtain that velocity. This information is used in the design of wind tunnels. The quantity density times area times velocity has the dimensions of mass/time and is called the mass flow rate. This quantity is an important parameter in determining the thrust produced by a propulsion system. As the speed of the flow approaches the speed of sound the density of the flow is no longer a constant and we must then use a compressible form of the mass flow rate equation. The conservation of mass equation also occurs in a differential form as part of the Navier Stokes equations of fluid flow. Mass = density times volume, Examples of mass conservation in solid mechanics, fluid statics, and fluid dynamics [7].

2.3 The Momentum Conservation Equation

The conservation of momentum is a fundamental concept conservation of energy conservation of mass Momentum is defined to be the mass of an object multiplied by the velocity of the object. The conservation of momentum states that, within some problem domain, the amount of momentum remains constant; momentum is neither created nor destroyed, but only changed through the action of forces as described by Newton's laws of motion [8]. Dealing with momentum is more difficult than dealing with mass and energy because momentum is a vector quantity having both a magnitude and a direction. Momentum is conserved in all three physical directions at the same time. It is even more difficult when dealing with a gas because forces in one direction can affect the momentum in another direction because of the collisions of many molecules. On this slide, present a very, very simplified flow problem where properties only change in one direction. The problem is further simplified by considering a steady flow which does not change with time and by limiting the forces to only those associated with the pressure, Let us consider the flow of a gas through a domain in which flow properties only change in one direction, which we will call "x". The gas enters the domain at station 1 with some velocity **u** and some pressure **p** and exits at station 2 with a different value of velocity and pressure. For simplicity, we will assume that the density **r** remains constant within the domain and that the area **A** through which the gas flows also remains constant. The location of stations 1 and 2 are separated by a distance called δx (Delta) a change with distance is referred to as a gradient to avoid confusion with a change with time which is called a rate. The velocity gradient is indicated by$\frac{\delta \mathbf{u}}{\delta \mathbf{x}}$**;** the change in velocity per change in distance. So at station 2, the velocity is given by the velocity at 1 plus the gradient times the distance

$$u_2 = u_1 + \left(\frac{\delta u}{\delta x}\right)\delta x \tag{2.3.1}$$

A similar expression gives the pressure at the exit:

$$P_2 = P_1 + \left(\frac{\delta P}{\delta x}\right)\delta x \tag{2.3.2}$$

Newton's second law of motion states that force **F** is equal to the change in momentum with respect to time. For an object with constant mass **m** this reduces to the mass times acceleration **a**. Acceleration is a change in velocity with a change in time $\boldsymbol{\frac{\delta u}{\delta t}}$ then:

$$F = ma = m\left(\frac{\delta u}{\delta t}\right) \tag{2.3.3}$$

The force in this problem comes from the pressure gradient. Since pressure is a force per unit area, the net force on our fluid domain is the pressure times the area at the exit minus the pressure times the area at the entrance.

$$F = -(PA)_2 - (PA)_1 = \frac{m(u_2 - u_1)}{\delta t} \tag{2.3.4}$$

The minus sign at the beginning of this expression is used because gases move from a region of high pressure to a region of low pressure; if the pressure increases with x, the velocity will decrease. Substituting for our expressions for velocity and pressure:

$$-\left(\left(p+\left(\frac{\delta p}{\delta x}\right)\delta x\right)A-(pA)\right)=m\left(\frac{u+\left(\frac{\delta u}{\delta x}\right)\delta x-u}{\delta t}\right) \quad (2.3.5)$$

It Simplify to:

$$-\left(\frac{\delta p}{\delta x}\right)\delta xA=\frac{m\left(\frac{\delta u}{\delta x}\right)\delta x}{\delta t} \quad (2.3.6)$$

Noting that (del x / del t) is the velocity and that the mass is the density $\boldsymbol{\rho}$ times the volume (area times del x):

$$-\left(\frac{\delta p}{\delta x}\right)\partial x\ A=\rho Vu\left(\frac{\delta u}{\delta x}\right) \quad (2.3.7)$$

It simplify to:

$$-\left(\frac{\delta p}{\delta x}\right)=\rho u\left(\frac{\delta u}{\delta x}\right) \quad (2.3.8)$$

The del p / del x and del u / del x represent the pressure and velocity gradients. If we shrink our domain down to differential sizes, these gradients become differentials [7]:

$$-\frac{\delta p}{\delta x}=\frac{\rho u\delta u}{\delta x} \quad (2.3.9)$$

2.4 Bernoulli’s equation

Bernoulli's principle can be derived from the principle of conservation of energy. This states that, in a steady flow, the sum of all forms of energy [5] in a fluid along a streamline is the same at all points on that streamline. This requires that the sum of kinetic energy, potential energy and internal energy remains constant. Thus an increase in the speed of the fluid – implying an increase in both its dynamic pressure and kinetic energy – occurs with a simultaneous decrease in (the sum of) its static pressure, potential energy and internal energy. If the fluid is flowing out of a reservoir, the sum of all forms of energy is the same on all streamlines because in a reservoir the energy per unit volume (the sum of pressure and gravitational potential $\rho\, g\, h$) is the same everywhere. Bernoulli's principle can also be derived directly from Newton's second law. If a small volume of fluid is flowing horizontally from a region of high pressure to a region of low pressure, then there is more pressure behind than in front. This gives a net force on the volume, accelerating it along the streamline. Fluid particles are subject only to pressure and their own weight. If a fluid is flowing horizontally and along a section of a streamline, where the speed increases it can only be because the fluid on that section has moved from a region of higher pressure to a region of lower pressure; and if its speed decreases, it can only be because it has moved from a region of lower pressure to a region of higher pressure. Consequently, within a fluid flowing horizontally, the highest speed occurs where the pressure is lowest, and the lowest speed occurs where the pressure is highest.

$$W = F.\Delta L \qquad (2.4.1)$$

Where w is work done, F is force,ΔL is distance.

But

$$\Delta L = V_1 \partial t \qquad (2.4.2)$$

$$F = P.A \qquad (2.4.3)$$

The liquid volume is V which flow at Δt

$$V = v_1 A_1 \tag{2.4.4}$$

Then the work done is:

$$W_1 = P_1 V_1 \Delta t \tag{2.4.5}$$

And

$$V = v_1 \Delta t \tag{2.4.6}$$

Since $W_2\ at\ t_2\ is$

$$W_2 = P_2 A_2 v_2 \Delta t \tag{2.4.7}$$

$$W_2 = P_2 V \tag{2.4.8}$$

Where the volume at $A_1, \Delta t\ its\ at\ A_2$ then the net force is:

$$W = W_1 - W_2 = P_1 V - P_2 V \tag{2.4.9}$$

$$W = (P_1 - P_2)V \tag{2.4.10}$$

$$\frac{W}{V} = P_1 - P_2 \tag{2.4.11}$$

Now to determine kinetic energy E_{K1} of unit volume at A_1

$$E_{K1} = \frac{1}{2} m v_1^2 \tag{2.4.12}$$

$$\rho = \frac{m}{v} \tag{2.4.13}$$

Then kinetic energy for unit volume at A_2 is:

$$\frac{E_{K1}}{V} = \frac{1}{2}\rho v_1^2 \tag{2.4.14}$$

$$\frac{E_{K2}}{V} = \frac{1}{2}\rho v_2^2 \tag{2.4.15}$$

Where ρ is constant then

$$\frac{\Delta E_k}{V} = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 \tag{2.4.16}$$

Where potential energy E_P in unit volume is:

$$E_{p1} = mgy_1 \tag{2.4.17}$$

$$\frac{E_{P1}}{V} = \rho g y_1 \tag{2.4.18}$$

At $A_1$and at $A_2$is:

$$E_{p2} = mgy_2, \frac{E_{p2}}{V} = \rho g y_2 \tag{2.4.19}$$

$$\frac{\Delta E_p}{V} = \rho g(y_2 - y_1) \tag{2.4.20}$$

By applying the conservation of energy

$$P_2 - P_{s1} = \left(\frac{1}{2}\rho v_1^2 - \frac{1}{2}\rho v_2^2\right) + (\rho g y_2 - \rho g y_1) \tag{2.4.21}$$

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2 \tag{2.4.22}$$

$$P + \frac{1}{2}\rho v^2 + \rho g y = constant \qquad (2.4.23)$$

In most flows of liquids, and of gases at low Mach number, the density of a fluid parcel can be considered to be constant, regardless of pressure variations in the flow. Therefore, the fluid can be considered to be incompressible and these flows are called incompressible flow. Bernoulli performed his experiments on liquids, so his equation in its original form is valid only for incompressible flow. A common form of Bernoulli's equation, valid at any arbitrary point along a streamline, The Bernoulli’s equation is one of the most useful equations that is applauding wide variety of fluid flow related problems. This equation can be derived in different ways, e.g. by integrating Euler’s equation along a streamline, by applying first and second laws of thermodynamics to steady ,irrigational , inviscid and incompressible flows in simple form the Bernoulli’s equation relates the pressure velocity and elevation between any two points in the flow field. It is a scalar equation and is given by

$$\frac{P}{\rho g} + \frac{V^2}{2g} + Z = H = constant \qquad (2.4.24)$$

Each term in the above equation has dimensions of length (meters in SI units) hence these terms are called as $\frac{P}{\rho g}$ is the pressure head, $\frac{V^2}{2g}$ is the velocity head, Z is the static head and H is the total heads respectively. Bernoulli’s equation can also be written in terms of pressures (Pascal in SI units) as:

$$P + \rho\frac{V^2}{2} + \rho g z = P_t \qquad (2.4.25)$$

Between any two points 1 and 2 in the flow field for irrotational flows, the Bernoulli’s equation is written as:

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 \tag{2.4.26}$$

Bernoulli's equation can also be considered to be an alternate statement of conservation of energy (first law of thermodynamics) the equation also implies the possibility of conversion of one form of pressure into other. For example neglecting the pressure changes due to datum, it can be concluded from Bernoulli's equation that the static pressure rises in the direction of flow in a diffuser while it drops in the direction of flow in case of nozzle due to conversion of velocity pressure into static pressure and vice versa. Since all real fluids have finite viscosity, i.e. in all actual fluid flows, some energy will be lost in overcoming friction. This is referred to as head loss, i.e. if the fluid were to rise in vertical pipe it will raise to a lower to higher than predicted by Bernoulli equation the head loss will cause the pressure to decrease in flow if the head loss is denoted by H_1then Bernoulli equation can be modified to:

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{2g} + z_2 + H_1 \tag{2.4.27}$$

Since the total pressure reduces in the direction of flow.

2.5 The Navier -Stokes Equation

2.5.1 Euler's Equation

The fluid velocity u of an inviscid (ideal) fluid of density ρ under the action of a body force ρf is determined by the equation:

$$\frac{\rho Du}{Dt} = \Delta P + \rho f \tag{2.5.1.1}$$

Known as Euler's equation the scalar p is the pressure. This equation is supplemented by an equation describing the conservation of mass, for an incompressible fluid this is simply

$$\nabla . u = 0 \tag{2.5.1.2}$$

Real fluids however are never truly inviscid. We must therefore see how equation (1) is changed by the inclusion of viscous forces, the stress tensor we must introduce the stress tensor σ_{ij} as follow σ_{ij} pointing in the j-direction, then t is the stress on a small surface element δs with unit normal n it is straight forward to demonstrate that:

$$t_i = \sigma_{ij} n_j \tag{2.5.1.3}$$

2.5.2 The Equation of Motion

The i^{th} component of force exerted by the surrounding fluid on a fluid blob with surface S and volume V is given by

$$\int t_i \, ds = \int \sigma_{ij} n_j \, ds = \int \frac{\partial \sigma_{ij}}{\partial x_i} dV \tag{2.5.2.1}$$

Where we have used relations together with the divergence theorem Applying Newton's second law to an arbitrary fluid blob then leads to the equation of motion

$$\frac{\rho D u_i}{Dt} = \frac{\partial \sigma_{ij}}{\partial x_j} + \rho f_i \tag{2.5.2.3}$$

Applying an argument involving $\sigma\delta$g angular momentum to a tetrahedron, which is similar in spirit to the argument above using linear momentum, leads to the result that the tensor σij is symmetric.

2.5.3 Newtonian Fluids

In order actually to solve equation (3) it is necessary to relate the stress tensor σij to the fluid velocity u. We shall restrict our attention to fluids that are incompressible and for which the stress tensor is assumed to take the form:

$$\sigma ij = -p\delta_{ij} + \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) \quad (2.5.3.1)$$

Where μ the viscosity and p is the pressure. Note that σ_{ij} is symmetric, as required Fluids for which the linear relation (1) holds are said to be Newtonian in recognition of the fact that Newton proposed such a relation for a simple shearing motion For water and for most gases under non-extreme conditions the linear relation (1) holds there are though many important fluids that are non-Newtonian the simple relation (3) does not hold. These include paint tomato ketchup, blood, toothpaste and quicksand. Note that, since

$$\nabla . u = 0 \quad (2.5.3.2)$$

Then

$$P = -\frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) \quad (2.5.3.3)$$

P is the mean of the three normal stresses; the final step in deriving the Navier-Stokes equation is to substitute expression (1) for σ_{ij} into equation (1). This leads to the equation (assuming constant viscosity),

$$\frac{\rho Du}{Dt} = -\nabla p + \rho f + \mu \nabla^2 u \quad (2.5.3.4)$$

Equation (4) is known as the Navier-Stokes equation for an incompressible Fluid; it is to be solved in conjunction with the incompressibility condition (2) for compressible fluids the viscous term is a little more complicated. Assuming that the density is constant, equation (4) can be written as

$$\frac{Du}{Dt} = \frac{1}{\rho}\nabla p + f + v\nabla^2 u \quad (2.5.3.5)$$

Where

$$v = \frac{\mu}{\rho} \tag{2.5.3.6}$$

Is the kinematic viscosity, it is often helpful to express the Navier-Stokes equation in dimensionless form. Suppose a low has characteristic length scale L and characteristic velocity scale U. Then we may introduce dimensionless variables (denoted by tildes) as follows:

$$u = U\,\tilde{}u; \quad t = \frac{L}{U}\tilde{}t \qquad \frac{\partial}{\partial x} = \frac{1}{L}\frac{\partial}{\partial \sim x} \quad p = \rho U^2 \sim p;\, f = \frac{U^2 \sim f}{L} \tag{2.5.3.7}$$

0n substituting into (5), and dropping the tildes, we obtain the dimensionless Navier-Stokes equation [9].

$$\frac{Du}{Dt} = -\nabla p + f + \frac{1}{Re}\nabla^2 u \tag{2.5.3.8}$$

Where Re = UL/v is the Reynolds number

2.6 Equation of Continuity

General expressions can be utilized to determine velocity distributions for flow systems. This method is better than developing formulations peculiar to the specific problem at hand. The general momentum equation is also called the equation of motion or the Navier-Stoke's equation; in addition the equation of continuity is frequently used in conjunction the equation of continuity is developed simply by applying the law of conservation of mass to a small volume element within a flowing fluid. The momentum equation [10] the equation of motion or the Navier-Stoke's equation is an extension of p previously written momentum balance. The equation of continuity the momentum equation most of the fluid flow problems can be mathematically described by these two equations due to the conservation of mass: (rate of mass accumulation) = (rate of mass in) – (rate of mass out)

Consider a stationary volume within a fluid moving with a velocity having the components:

$$v_z, v_y, v_x \tag{2.6.1}$$

The volume flow rate of fluid (VFR) in or out across the face =

The velocity x the cross-sectional area

The rate of mass in or out through the face = (VFR) x density of fluid

$$\Delta x \Delta y \Delta z \frac{\partial p}{\partial t} = \Delta y \Delta z\left[\rho v_{x|x} - \rho v_{x|x+\Delta x}\right] + \Delta x \Delta z\left[\rho v_{y|y} - \rho v_{y|y+\Delta y}\right] + \Delta x \Delta y\left[\rho v_{z|z} - \rho v_{z|z+\Delta z}\right] \tag{6.2.2}$$

Then dividing through by Δx Δy Δz, and taking the limit as these dimensions approach zero, we get the equation of continuity:

$$\frac{dp}{dt} = -\left(\frac{\partial}{\partial x}\rho v_x + \frac{\partial}{\partial y}\rho v_y + \frac{\partial}{\partial z}\rho v_z\right) = -\nabla . \rho v \tag{2.6.3}$$

If the fluid density is constant then the Continuity equation

$$0 = \frac{d}{dx}v_x + \frac{d}{dy}v_y + \frac{d}{dz}v_z \tag{2.6.4}$$

Or in vector notation

$$\nabla . v = 0 \tag{2.6.5}$$

When the previous momentum balance equation is extended to include unsteady-state systems ;(rate of momentum accumulation) = (rate of momentum in) - (rate of momentum out) + (sum of forces acting on the system) [11].

2.7 Relation between Viscosity and Density

The SI system of units the kilogram (kg) is the standard unit of mass, a cubic meter is the standard unit of volume and the second is the standard unit of time. The density of a fluid is obtained by dividing the mass of the fluid by the volume of the fluid. Density is normally expressed as kg per cubic meter p = kg/m^3

$$\rho = \frac{m}{v} \tag{2.7.1}$$

Sometimes the term 'Relative Density' is used to describe the density of a fluid. Relative density is the fluid density divide by 1000 kg/m^3 Viscosity describes a fluids resistance to flow Dynamic viscosity sometimes referred to as absolute viscosity is obtained by dividing the Shear stress by the rate of shear strain. The units of dynamic viscosity are: Force /area x time The Pascal unit (Pa) is used to describe pressure or stress = force per area this unit can be combined with time (sec) to define dynamic viscosity (Pa.s) the flow of a known volume of fluid from a viscosity measuring cup. The timings can be used along with a formula to estimate the kinematic viscosity value of the fluid the motive force driving the fluid out of the cup is the head of fluid. This fluid head is also part of the equation that makes up the volume of the fluid. Rationalizing the equations the fluid head term is eliminated leaving the units of Kinematic viscosity as area / time v = m^2/s, velocity gradient $\frac{\Delta v}{\Delta h}$ When tangential stress is

$$\frac{f}{A} \tag{2.7.2}$$

A is the area, viscosity coefficient η is the rate of stress and strain

$$\eta = \frac{F/A}{v/h} \tag{2.7.3}$$

$$F = ma \tag{2.7.4}$$

F is the force a is the acceleration the force of sheer resulting of viscosity is given by:

$$F = 2\pi rv \tag{2.7.5}$$

Then

$$mg = 6\pi\eta rv \tag{2.7.6}$$

The volume equal to

$$\frac{4}{3}\pi r^3 \tag{2.7.7}$$

$$\frac{4}{3}\pi r^3(\rho - \delta)g = 6\pi\eta r \tag{2.7.8}$$

$$\eta = \frac{2gr^2(\rho - \delta)}{9v} \tag{2.7.9}$$

2.8 Fluid Flow in Pipes

Here is the flow of real fluid in pipes – real meaning a fluid that possesses viscosity hence looses energy due to friction as fluid particles interact with one another and the pipe wall. Recall from Level 1 that the shear stress induced in a fluid flowing near a boundary is given by Newton's law of viscosity [12] .

$$\tau \propto \frac{du}{dy} \tag{2.8.1}$$

This tells us that the shear stress, τ, in a fluid is proportional to the velocity gradient the rate of change of velocity across the fluid path. For a "Newtonian" fluid

$$\tau = \mu \left(\frac{du}{dy}\right) \tag{2.8.2}$$

Where the constant of proportionality, μ, is known as the coefficient of viscosity (or simply viscosity).Recall also that flow can be classified into one of two types, laminar or turbulent flow (with a small transitional region between these two). The non-dimensional number, the Reynolds number, Re, is used to determine which type of flow occurs:

$$\text{Re} = \frac{\rho u d}{\mu} \tag{2.8.3}$$

For a pipe Laminar flow: Re < 2000, Transitional flow: 2000 < Re < 4000,Turbulent flow: Re > 4000 it is important to determine the flow type as this governs how the amount of energy lost to friction relates to the velocity of the flow. And hence how much energy must be used to move the fluid.

Chapter Three

Blood Pressure

3.1 Definition of Blood Pressure

Arterial blood pressure is the force exerted by the blood on the wall of a blood vessel the heart (Figure 1) pumps (contracts) and relaxes. Systolic blood pressure is the degree of force when the heart is pumping (contracting). The diastolic blood pressure is the degree of force when the hearts relaxed. Blood pressure is summarized by two measurements, systolic and diastolic, which depend on whether the heart muscle is contracting (systole) or relaxed between beats (diastole) and equate to a maximum and minimum pressure, respectively. Normal blood pressure at rest is within the range of 100-140mmHg systolic (top reading) and 60-90mmHg diastolic (bottom reading). High blood pressure is said to be present if it is persistently at or above 140/90 mmHg [13].

3.2 Meaning of Blood Pressure

Risk of illness and death are related to changes in blood pressure. There is no particular dividing line which indicates a person is definitely ill. This can be interpreted only by a physician in light of the total health picture of the individual. Specific instructions will be followed in reporting the blood pressure measurements to the subject. This action is taken so that the subject is informed of any findings that are outside of normal limits.

3.3 Factors that Affect Blood Pressure

Blood pressure is affected by several factors:

• Peripheral resistance

• Vessel elasticity

• Blood volume

• Cardiac output

Sources of Peripheral Resistance

One of the main factors that affect blood pressure is peripheral resistance; Blood cells and plasma encounter resistance when they contact blood vessel walls if resistance increases, then more pressure is needed to keep blood moving.

Three main sources of peripheral resistance:

1. Blood vessel diameter
2. Blood viscosity
3. Total vessel length

Vessel Diameter Analogy Vessel diameter affects peripheral resistance. As the diameter of a tube gets smaller, a greater proportion of the fluid is in contact with the wall of the tube. Therefore resistance to flow is increased and pressure raises larger diameter, same volume, less pressure. Smaller diameter, same volume, more pressure.

Vasomotor Fibers

Constriction of blood vessels raises blood pressure. Vessel diameter is actively regulated by vasomotor fibers, sympathetic nerve fibers that innervate the vessel's smooth muscle layer. Vasomotor fibers release norepinephrine, a powerful vasoconstrictor. A vasoconstrictor is a substance that causes blood vessels to constrict.

Vasoconstrictors

Blood vessel diameter is also regulated by blood-borne vasoconstrictors. Record the effect of each of these chemicals on the blood vessel: Epinephrine, Angiotensin II, and Vasopressin.

Viscosity Demonstration

Blood viscosity affects peripheral resistance. Viscosity is related to the thickness of a fluid. The greater the viscosity, the less easily molecules slide past one another and the more difficult it is to get the fluid moving and keep it moving. Because of this greater resistance to flow, a greater pressure is required to pump the same volume of viscous fluid. Total Vessel Length The hematocrit is the percentage of red blood cells in the total blood volume. The hematocrit affects blood viscosity and therefore resistance to flow. The more viscous the blood, the greater resistance it encounters and the higher the blood pressure. The hematocrit can increase when there are more red blood cells or less plasma in the blood. The hematocrit can decrease when there are fewer red blood cells or more plasma.

Vessel Length

Total vessel length affects peripheral resistance. Increased fatty tissue requires more blood vessels to service it and adds to the total vessel length in the body. The longer the total vessel length, the greater the resistance encountered, and the greater the blood pressure.

Vessel Elasticity

Besides peripheral resistance, blood vessel elasticity also affects blood pressure. A healthy elastic artery expands, absorbing the shock of systolic pressure. The elastic recoil of the vessel then maintains the continued flow of blood during diastole. When an individual has arteriosclerosis, arteries become calcified and rigid, so they can't expand when the pulse wave of systolic pressure passes through them. Thus the walls of the artery experience higher pressures and become weaker and weaker.

Blood Volume Analogy

Blood volume affects blood pressure, when there is a greater volume of fluid, more fluid presses against the walls of the arteries resulting in a greater pressure. When there is less volume there is less pressure.

Example: Reduced blood volume (for example due to excessive sweating) reduces blood pressure [14] .

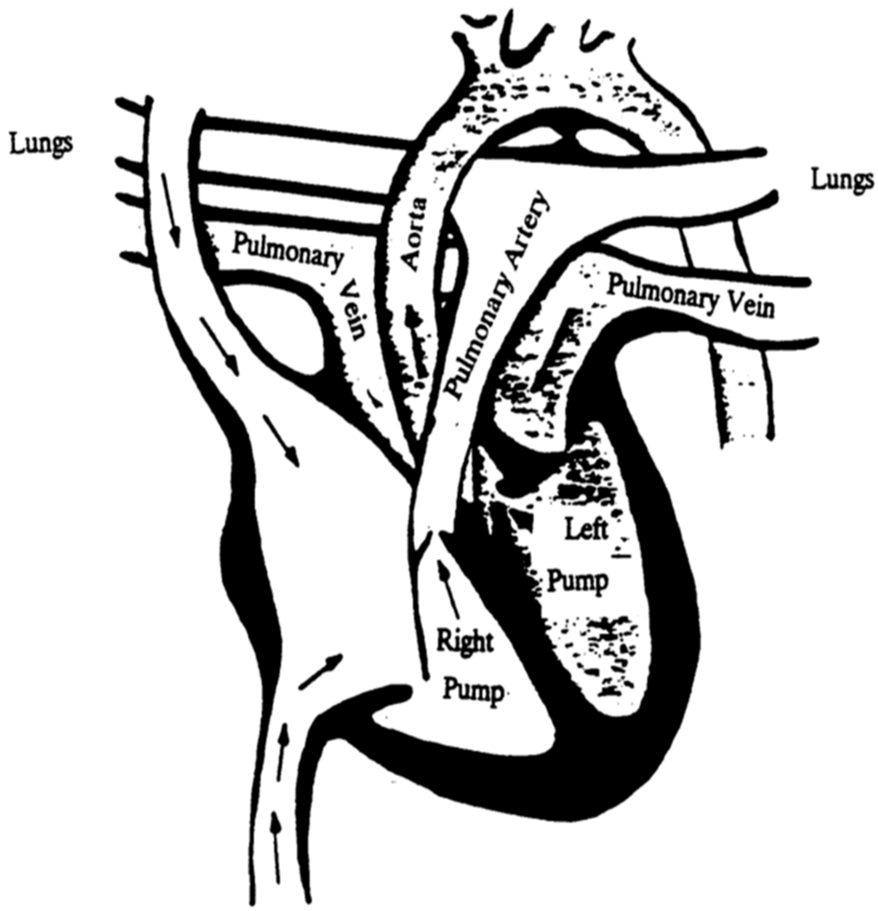

Fig (3.1) the heart

3.4 Method of Measuring Arterial Blood Pressure

In the measurement procedure a cuff is wrapped around a person's arm with an inflatable rubber bag inside the cuff centered over the brachial artery. Enough air pressure is pumped into the cuff to close the artery. Air pressure is then released by opening the thumb valve. When the pressure in the cuff is equal to the pressure on the artery, the artery opens and the blood begins to return to the part of the artery that was closed. As the blood returns to the artery, pulse sounds begin. These sounds can be heard through a stethoscope placed over the brachial pulse point. The sounds continue for a time while the cuff is deflated slowly, eventually becoming too faint to hear. The cuff is connected by tubing to a manometer, which shows the amount of pressure on the artery. When the first pulse sounds are heard, the reading on the manometer measures the systolic blood pressure. The last sound heard is the diastolic blood pressure. In children, the muffling of sound or fourth sound is often used as the diastolic blood pressure rather than the disappearance of sound.

4.4 Blood Pressure Equipment

The set of equipment which will be used for measuring blood pressure in the arteries consist of:

a- Bauman meter, mercury - gravity Rx model, with case from which the pressures heard.

b- Blood pressure cuffs, Baum calibrated, V-Look cuffs, child, adult, large arm and Thigh sizes, each with a complete inflation system which has an unyielding compression cuff containing an inflatable rubber bladder, a pressure bulb, and a pressure control valve to control the rate of deflation the infant cuff will not be used because the pulse and blood pressure measurements will be done on Adults age seventeen years and older.

c- A Littman Classic Stethoscope with combination head, diaphragm and bell to hear pulse sounds (Figure 3).

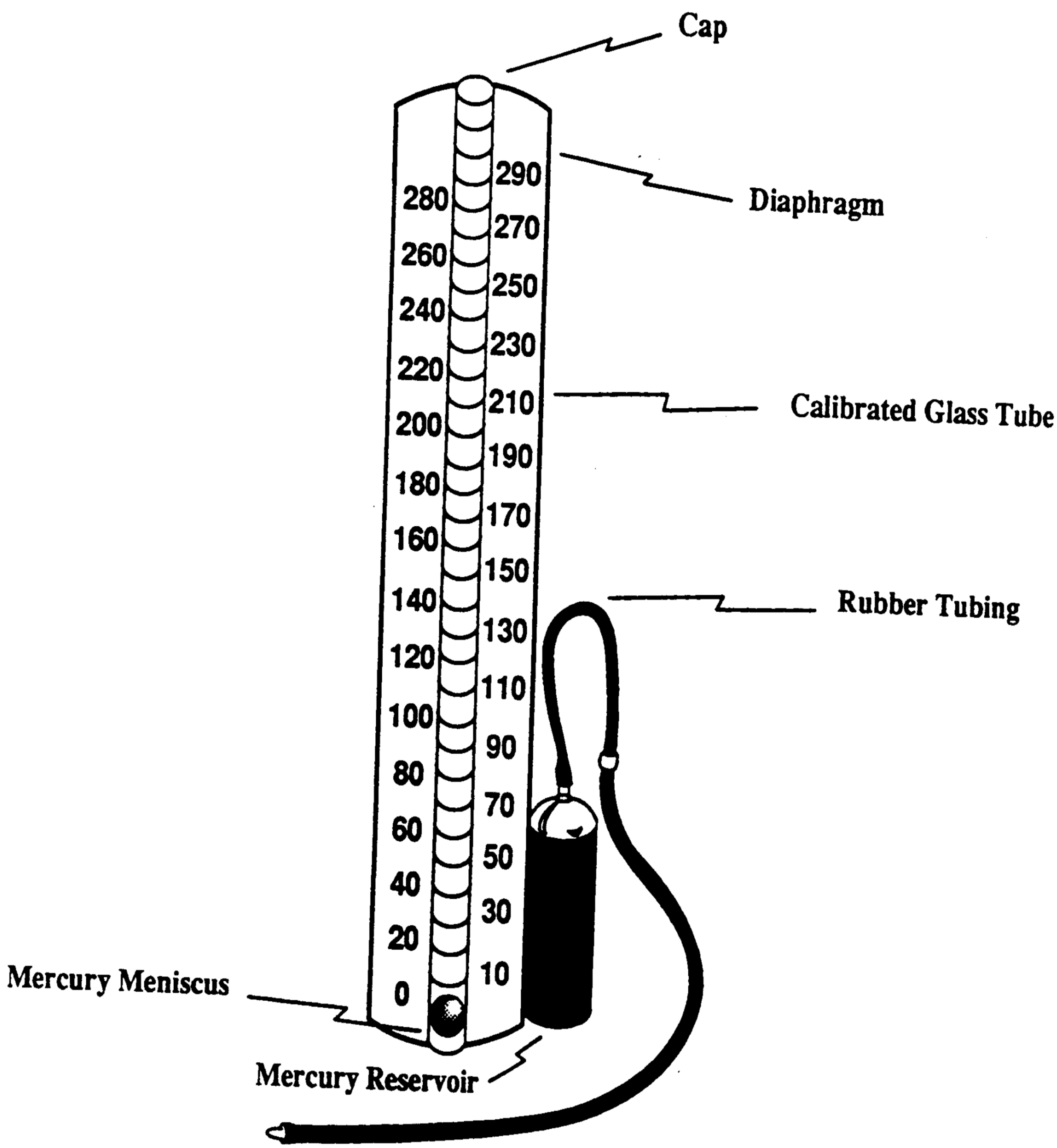

Fig (3.1) Manometer

3.5.1 Manometer:

The mercury-gravity manometer (Figure 2) consists of a calibrated glass tube connected to a reservoir containing mercury. The mercury reservoir communicates with a compression cuff through a rubber tube. When air pressure is exerted on the mercury in the reservoir, by pumping the pressure bulb, the mercury in the glass tube rises and indicates how much pressure; the cuff is applying against the artery .The mercury manometer is calibrated when it is manufactured and, once calibrated, recalibration is unnecessary. However, regular inspection is necessary to eliminate conditions that could cause the blood pressure measurement to be read as erroneously high or low .The level of mercury in the calibrated glass tube should always be at the zero line when the manometer is on a level surface with the inflation system disconnected. If the level of mercury is above or below the zero line, the cause may be too much mercury in the reservoir, mercury leak, or dirt in the mercury or in the calibrated glass tube. Tip the manometer gently to the right and then back to the erect position. If the top of the mercury column does not return to zero, replace the equipment. If the shape of the mercury meniscus (top of the column of mercury) is not a smooth, well-defined curve, replace the equipment. This is also caused by dirt in the mercury or the glass tube. If the mercury does not rise easily in the tube, or if the mercury column bounces noticeably as the valve is closed, replace the equipment. The atmospheric pressure within the tube has been altered. Mercury Spills and Leaks Mercury is a metallic substance which gives off a toxic vapor when exposed to the atmosphere. Temperature, ventilation, and sunlight affect the level of the vapor’s concentration check the cap at the top of the calibrated glass tubing. If it is not securely closed, the mercury could leak out. Mercury leaks may also occur if the manometer case itself is not stored properly [15].

Before closing the manometer case, always make sure that the: Manometer tubing is connected and the thumb valve is closed; and Manometer case is stored by placing the case on its right side. This will allow the mercury to flow back into the reservoir. Loss of air and mercury will occur if the glass tube is broken. Care should be taken in handling and storing the manometer to prevent this. If the tube appears cracked, check for any spilled mercury in and outside the manometer cause and replace the equipment if necessary Hg is the chemical symbol for mercury pressure control valve controls the rate at which the system is deflated. To close the valve, or inflate the cuff, the valve is turned with the thumb toward you. To open the valve, or deflate the cuff, the valve should be turned with the thumb away from you. Each cuff size will have a complete inflation system. These are easily attached by a twist connection to the manometer. It will not be necessary to exchange inflation bulbs and valves with the various cuffs. The cuffs, pressure bulb, and manometer and manometer tubing will be checked each day, before use, for cracks, tears and/or air leaks. The pressure control valve will be checked each day, before use, for sticking. To test for air leaks in the inflation system, wrap the compression cuff around a one pound coffee can or similar object Close the pressure control valve and inflate the pressure to 250 mm Hg., then decrease the pressure to 200 mm Hg. Close the pressure control valve. Wait for ten seconds. If the mercury column falls more than 10mmHg there is a leak in the inflation system Use the coffee the adult, large arm, and thigh compression cuff. Use a soda can for the child’s compression cuff. Check for tears in the compression cuff and for cracks or punctures in the rubber tubing and rubber pressure bulb. Check that the pressure control valve does not stick. If an air leak is located, the compression cuff is torn, or the valve or connections do not operate properly, do not measure additional blood pressures with this equipment.

3.5.2 Stethoscope

The stethoscope [figure 3] is an instrument for listening to sounds within the body. Body sounds can be heard at the skin's surface and transported via enclosed columns of air to the ear In order to take the blood pressure, the stethoscope diaphragm is applied directly over the brachial pulse pressure point (inner arm). The diaphragm headpiece should be applied with light pressure (heavy pressure will distort the artery and produce sounds below the true diastolic) so that there is no air between the skin and the stethoscope. In using stethoscopes with bent ear tips, the ear tips should point forward toward the nose. Select the diaphragm as opposed to the open bell head of the stethoscope by holding the stem of the head in one hand and rotating the head with the other hand until a click is felt. The small hole located in the center of the bell head should be closed. The Blood Pressure Measurement form will be used for recording information about the pulse and blood pressure. In measuring the SP's pulse and blood pressure, the maximum inflation level will be determined, the pulse counted, and the three blood pressure readings obtained. For simplicity, all blood pressure measurements will be made on the SP's right arm. Where this is not feasible the left arm will be utilized and the exception noted on the Blood Pressure Measurement form.

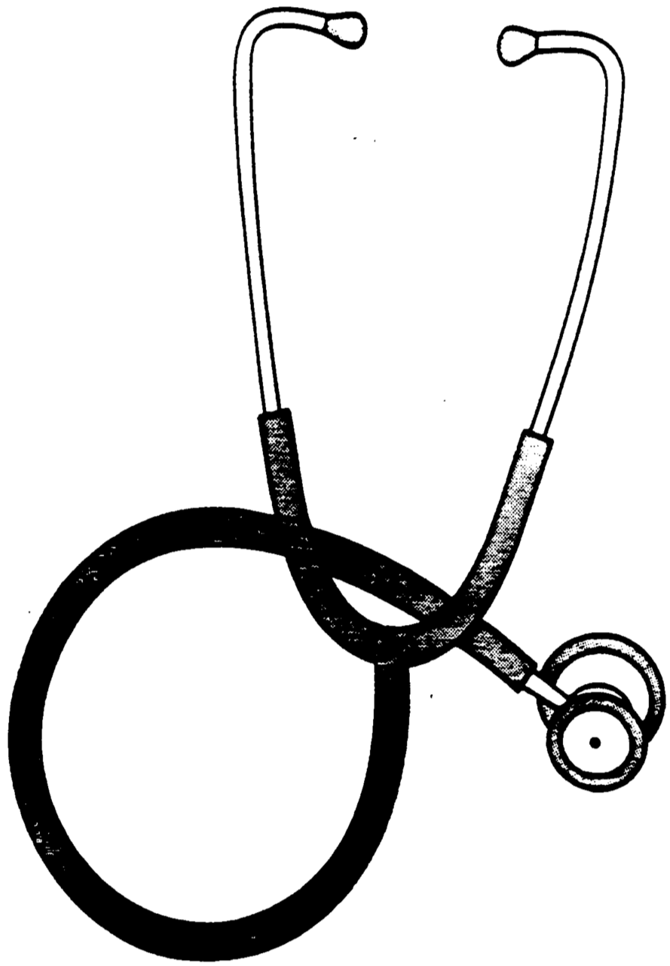

Fig (3.3) Stethoscope

If the adult for whom the blood pressure is being taken indicates any reason why the blood pressure procedure should not be done on the right arm, use the left. If there is a problem with both arms, do not take the blood pressure and note this on the Blood Pressure Measurement form. Observe the adult's arm while talking to him/her. If you observe any rashes, small gauze / adhesive dressings, casts, withered arms, puffiness, tubes, open sores, hematomas or wounds on both arms, do not take the blood pressure. If these conditions prevent measuring pulse, provide an explanation on the Blood Pressure Measurement form. Shoulder, taking care that two fingers may be placed under the sleeve without difficulty. The SP's right arm will be placed on the table, slightly flexed with palm upward. The SP's arm should be positioned so that it is resting on the table at heart level. Heart level is halfway between the shoulders and the waist. The person's elbow must be no lower than the lowest rib and must not be raised as high as the shoulder. For tall people it may be necessary to support the arm higher than a standard desk or table top. Place the tall person's forearm on a pillow, large book or directory to raise the arm to heart level. For smaller or short adults, place a cushion or large book on the chair so their arm is at heart level when it is resting on the desk or table top. Place a box or large book under their feet if they do not rest flat on the floor. The interviewer will be seated facing and slightly to the SP's right, permitting easy access to the SP's arm. Equipment will be positioned so that; the tube to the manometer is away from the SP's body while the tube to the inflation bulb is closer to the body. Should the SP be bedridden, measure the blood pressure with the SP in bed Place a table or night stand next to the bed to support the manometer both arms; do not take the blood pressure. If these conditions prevent measuring pulse, provide an explanation on the Blood Pressure Measurement form.

3.6 Determine the maximum Inflation level (MIL)

To measure the maximum inflation level (MIL), connect the inflation tubing to the manometer by twisting the two ends of the tubing together. The MIL is obtained to determine the highest level to which the cuff should be inflated. If the cuff is underinflated and the SP has an auscultator gap, a falsely low reading will result. If the cuff is overinflated a falsely high reading could result. The MIL will then be determine: Locate the radial pulse pressure point in the arm to be used. Close the thumb valve. Palpate the radial pulse and watch the center of the mercury column of the manometer.

Inflate the cuff quickly to 80 mm Hg, and then inflate in increments of 10 mm Hg until the radial pulse disappears, noting the reading of the mercury column at that point. Continue inflating the cuff at increments of 10 mm Hg, pausing briefly to make sure the pulse is absent. Continue 30 mm Hg higher to make sure the radial pulse has disappeared. To determine the appropriate statement to be read to the SP on the report of pulse and blood pressure on findings form Enhancement procedures were used on the second and third determinations. SP opened and closed fist 8-10 times and/or raised arm for 60 seconds.

3.7 Blood flowing through our body

The radius of the aorta is ~ 10 mm

the blood flowing through it has a speed ~ 300 $mm.s^{-1}$.

A capillary has a radius ~ 4×10^{-3} mm

but there are literally billions of them.

The average speed of blood through the capillaries 5×10^{-4} $m.s^{-1}$.

Calculate the effective cross sectional area of the capillaries and the approximate number of capillaries Setup aorta

RA = 10×10^{-3}m =10mm … and AA=cross sectional area of aorta capillaries

RC = 4×10^{-6}m =0.004mm … and AC =cross sectional area of capillaries aorta v A = 0.300 $m.s^{-1}$

Capillaries v C = $5\times10^{-4}m.s^{-1}$

Assume steady flow of an ideal fluid and apply the equation of continuity

Q = A v = constant ⇒ AA v A = AC v C

Area of capillaries AC

AC = AA (v A / v C) = π R

2 (v A / v c)

AC = 0.20 m^2

Number of capillaries N

AC = N π RC

N = AC / (π RC2) = 0.2 / {π (4×10-6)2}

Chapter Four

Experiments and Results

4.1 Introduction

The blood pressure plays an important role in human health .Therefore it is important to study the physical factors affecting the blood pressure. This experiment is devoted to show how the addition of fluids to blood changes its pressure.

4.2 Object

Study the rate of blood pressure when Dextrose Normal Saline (DNS 500 ml) infusion flows in patient body.

4.3 Apparatus

Blood pressure equipment, stethoscope, stop watch, dextrose (0.5) % normal saline (0.9) % infusion.

4.4 Methods

Inject intravenous DNS infusion to patient wait ten minutes and record its blood pressure repeat reading every ten minute.

4.5 Result

Tables 1, 2, 3: results of blood pressure variation with respect to the blood volume for patient in Asia Hospital every 10 minute.

Table (4.1): the change of systolic blood pressure with blood volume

t = time V = change of blood volume P = pressure of blood

t/sec	V/ 10-10m3	P- s /mm Hg
10	83.3	160
20	166.6	120
30	249.2	110
40	332.4	110
50	415.8	110
60	500	100

Table (4.2): the change of diastolic blood pressure with blood volume

t/sec	V/ 10-10m^3	P - d/mm Hg
10	83.3	110
20	166.6	80
30	249.2	80
40	332.4	70
50	415.8	60
60	500	60

Table (4.3): The change of blood pressure with change of blood volume

t/sec	V/10-10m3	BP/mm Hg
10	83.3	160/110
20	166.6	120/80
30	249.2	110/80
40	332.4	110/70
50	415.8	110/60
60	500	100/60

4.6 The chart

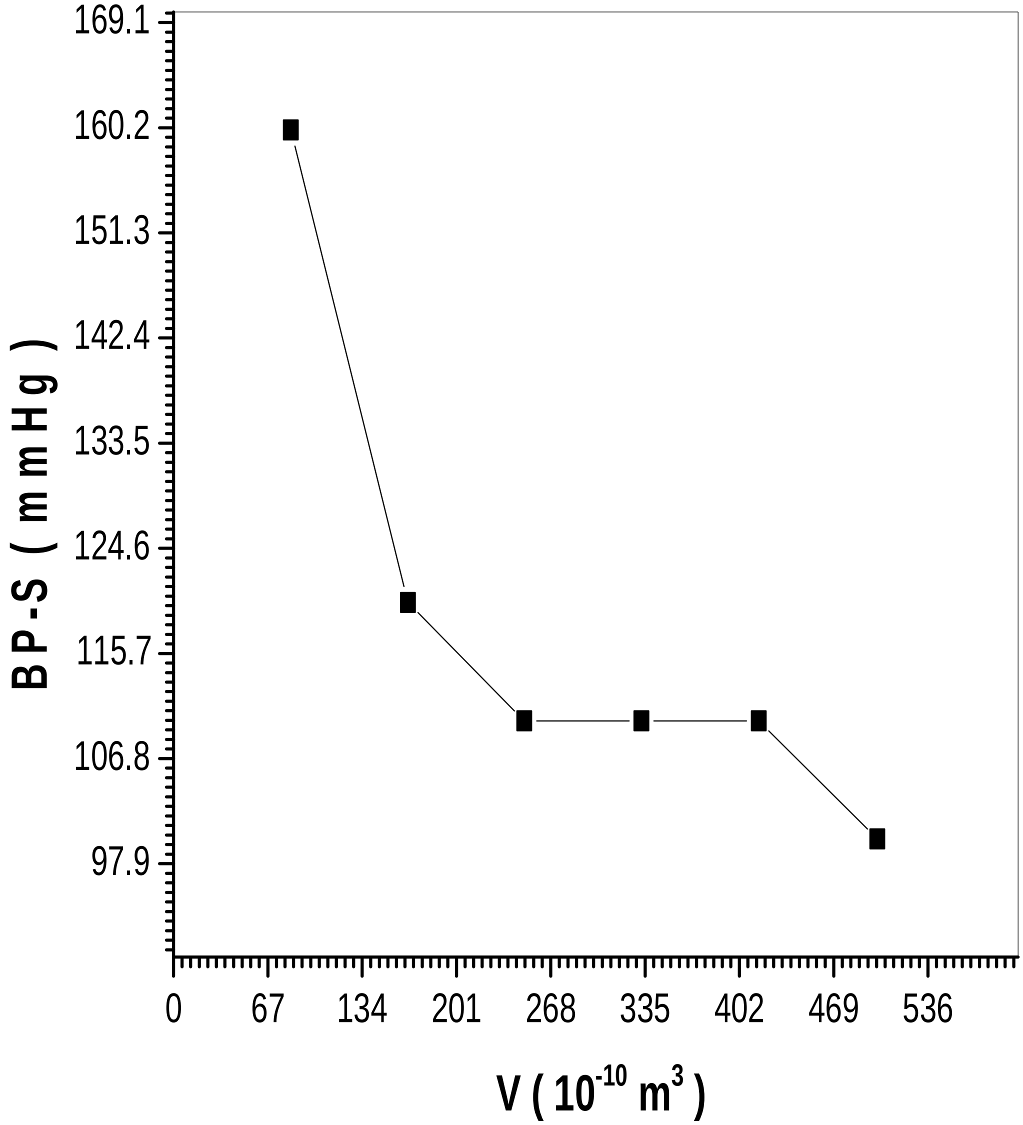

Fig (4.1) the relationship between systolic blood pressure and blood volume

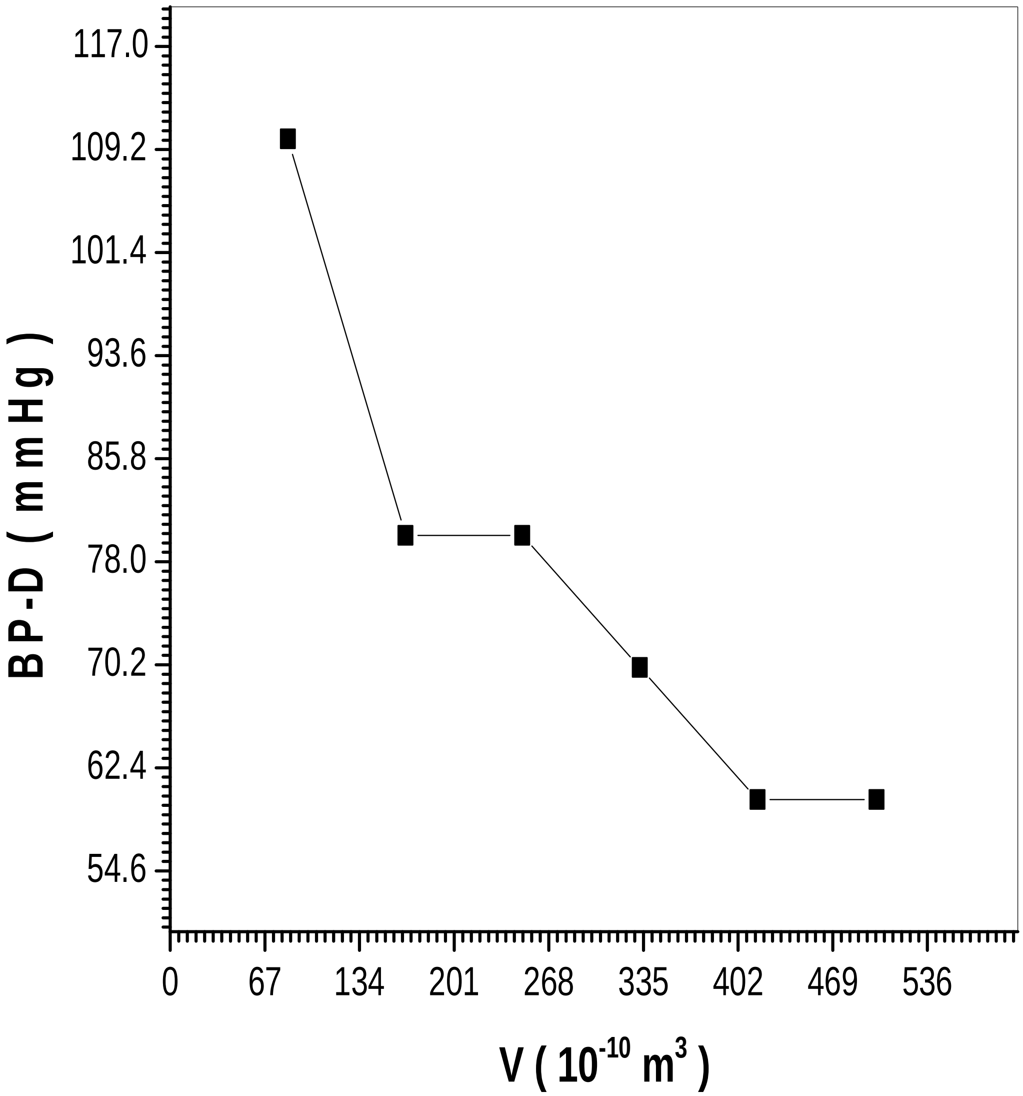

Fig (4.2) the relationship between diastolic blood pressure and blood volume.

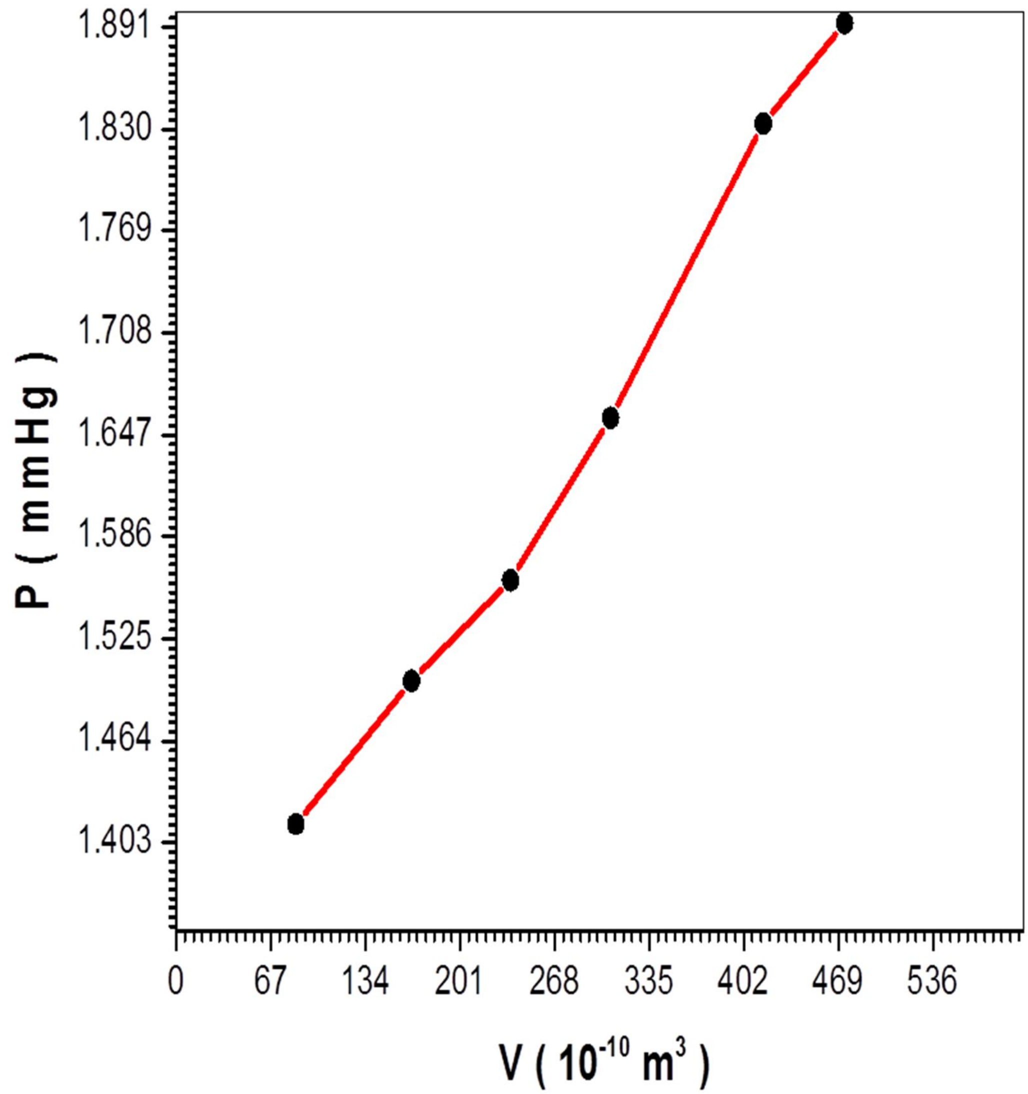

Fig (4.3) the relationship between blood pressure and blood volume.

4.7 Discussion

The experimental work done in this research shows the blood pressure decrease as its volume increase. This fact can be deduced straight forward from figures (4.1) and (4.2).It’s very easy to explain this empirical relation on the basic of continuity equation (2.6.3) and Bernoulli’s equation (2.4.25).According to continuity equation for flow in x- direction:

$$\frac{\partial \rho v_x}{\partial x} = 0$$

Thus for: $v_x = v$

$$\rho v = c_1 = constant \qquad (4.7.1)$$

Bernoulli’s equation when ignoring gravity effect reads:

$$P + \frac{1}{2}\rho v^2 = c_2 = constant \qquad (4.7.2)$$

Thus from (4.7.1):

$$v = \frac{c_1}{\rho}$$

Inserting this relation in (4.7.2) yields:

$$P + \frac{1}{2}\rho^{-1} c_1^2 = c_2 \qquad (4.7.3)$$

This equation means that, when blood pressure is feeded with Glucose water its density ρ decrease this increase the second term in equation (4.7.3) which decreases pressure.

4.8 Conclusion:

Diluting blood pressure by water can decrease blood pressure .Thus feeding human blood with water through glucose can control it.

4.9 Recommendations

More experiments need to be made to see how blood dilution by water can change and control blood pressure.

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