Pressure

Pressure is a very common phenomenon in our lives ,the service station attendant checks the pressure in our tires and the doctor measures our blood pressure as part of a physical examination.

The pressure P under a column of liquid can be calculated from the following low:

$$P = \rho g h$$

Where the: ρ is the density of the liquid

g is the acceleration due to the gravity

h is height of the column

Pressure is defined as the force per unit area in a gas or liquid. For a solid the quantity force per unit area is referred to as *stress*. In the metric system pressure is measured in dynes per square centimeter (Dy/cm^2) or Newton per square meter (N/m^2) or Pascal (Pa).

If the unit is Dy/cm^2

$$P = \rho g h$$

ρ = density of liquid (g/cm^3)

g=980(cm/sec^2) acceleration of gravity

h= in (cm) the height of liquid

Or …the unit is N/m^2

$$P = \rho g h$$

$\rho = (kg/m^3)$

g= 9.8 m/sec^2

h= in (m)

1atm $=1.01\times10^5$ N/m^2 =1033cmH_2O =760mmHg =76cmHg $=14.7 Ib/in^2$.(psi)

Ex1: Find the pressure of 10 m of water in Dy/cm^2 and N/m^2?

$10 \times 100 = 1000$ cm 1m=100cm

$\therefore P = \rho g h = 1\times980\times1000 = 980000 = 9.8\times10^5\ Dy/cm^2$

$P = \rho g h = 1000 \times 9.8 \times 10 = 9.8\times10^4\ N/m^2$

The most common method of indicating pressure in medicine is by the height of a column of mercury (Hg). For example , a peak (*systolic*)blood pressure reading of 120 mmHg indicates that a column of mercury of this height has a pressure at its base equal to the patients systolic blood pressure .

Ex2: Calculate the systolic pressure in Dy/cm^2 and N/m^2?

In systolic pressure =120 mmHg=12 cm Hg

= 0.12 m Hg

$\therefore P = \rho_{Hg}\, g\, h_{Hg} = 13.6\times980\times12 = 159936 = 1.6\times10^5\ Dy/cm^2$

$P = \rho_{Hg}\, g\, h_{Hg} = 13600\times9.8\times0.12 = 1.6\times10^4\ N/m^2$

Ex3:- what height of water will be produced the same pressure as 120 mmHg.

Solu.// $P= \rho\ g\ h= 13.6x980x12$

$=1.6x10^5\ dy/cm^2$

For water……. $P= \rho\ g\ h$

$1.6x10^5 =1x980xh$

So $h= 163$ cm H_2O

Or $P_{Hg} =P_{H2O}$

$(\rho\ g\ h)_{Hg} =(\rho\ g\ h)_{H2O}$

$\rho_{Hg}\ h_{Hg} = \rho_{H2O}\ h_{H2o}$

$h_{H2O} = (13.6x12)/1 =163\ cmH_2O$

Measurement of Pressure in the Body:

The instrument that measures pressure is called a *manometer*. A common type of *manometer* is U- shaped tube containing a fluid that is connected to the pressure to be measured Fig (1).

P_0= atmospheric pressure

h= height of liquid

P=the pressure of container.

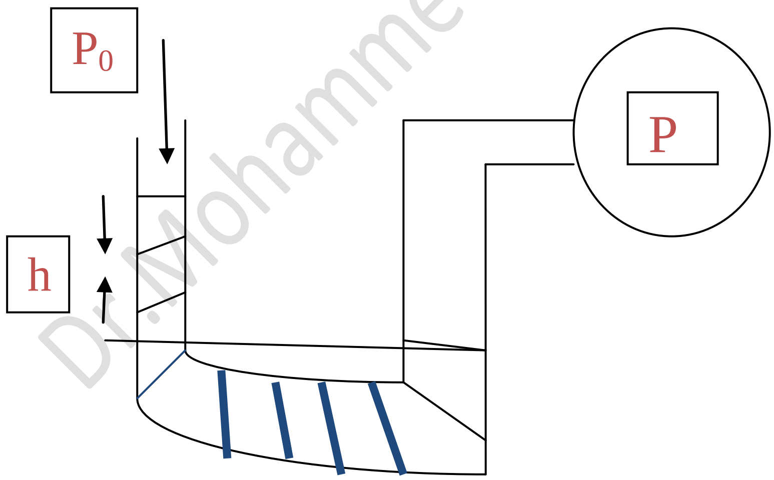


Fig (1): ***manometer***

The most common clinical instrument used in measuring pressure is the *sphygmomanometer* , which measures blood pressure. Two types of pressure gauges are used in sphygmomanometers.

1- Mercury manometers: height of a column of mercury inside a glass tube.

2- Aneroid: movement of a needle connected to a sealed flexible container.

Recently another type used (*digital*).

-*Gauge pressure* : is defined as the excess pressure over atmospheric pressure.

Gauge pressure $=\rho\, g\, h$

$=1000 \times 9.8 \text{x} 10$

$=10^5\ N/m^2 \quad = 1$ atm

-*Absolute pressure*=atmospheric pressure+ gauge pressure

$=1+1=2$ atm

Or In N/m^2

$=10^5 + 10^5 = 2\text{x}\ 10^5\ N/m^2$

Atmospheric pressure $= \rho_{Hg}\ g\ h_{Hg} \ =13600\text{x}\ 9.8\ \text{x}0.76$

$=10^5\ N/m^2$

Gauge pressure = pressure relative to atmospheric pressure

*Typical (gauge) pressures in *arterial blood pressure* as Maximum (systole) is (100-140 mmHg) and Minimum (diastole) is (60-90 mmHg) while *Venous blood pressure* (3-7 mmHg) .

Negative pressure:

Any pressure lower than atmospheric pressure. For example , when we breathe in (inspire)the pressure in the lungs must be lower than atmospheric pressure or the air would not flow in.

Pressure inside the skull :

The brain contains approximately 150 cm^3 of *cerebrospinal fluid* (CSF) in a series of interconnected openings called *ventricles*.

In CSF inside the brain, the typical pressure(5 – 12 mmHg). CSF (brain)→to ventricles→ to spinal column→ to circulatory system.

One of the ventricles, the aqueduct is especially narrow.

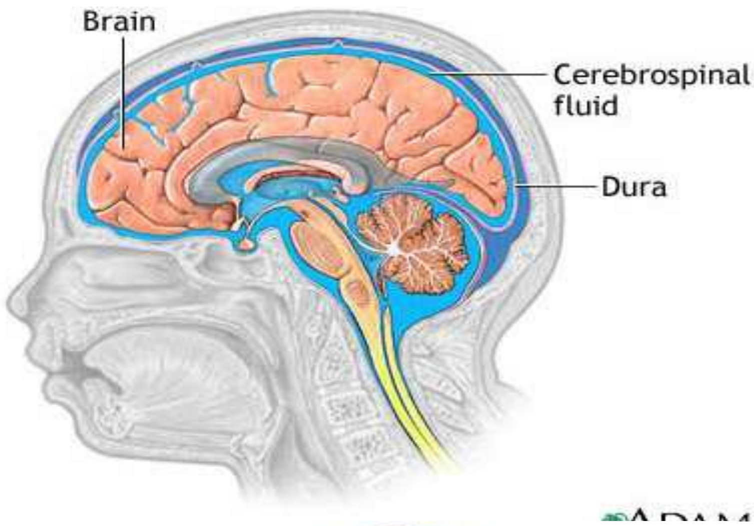
If at birth this opening is blocked for any reason, the CSF is trapped inside the skull and increased the internal pressure. This serious condition, called *hydrocephalus* (water head)

Measurement of hydrocephalus

1- Crude method: - In this method the circumference of the skull just above the ears .Normal values of newborn infants are from 32-37 cm, and larger than this may indicate *hydrocephalus*.
2- qualitative method (*transillumination*):-
   In this method light – scattering properties is used.

Blocked ventricle at birth →CSF is trapped inside the skull →internal pressure increases →enlarged skull

- Detection by circumference measurement (normal value: 32 ~ 37 cm)
- Detection by transillumination
- Surgical installation of by-pass drainage system.



Eye pressure:

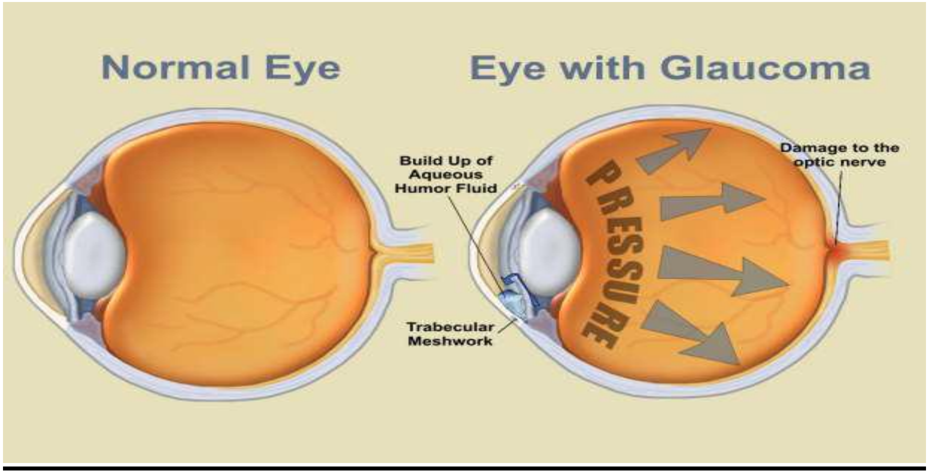
The clear fluids in the eye ball (aqueous and vitreous humors) that transmit the light to retina (the light sensitive part of the eye), are under pressure and maintain the eye ball in fixed size and shape.

If a partial blockage of the drain system occurs, the pressure increase then restrict the blood the blood supply to the retina then affect the vision. This condition, called *glaucoma*.

Glaucoma : a. Moderate ------------tunnel vision

b . Sever---------------blindness

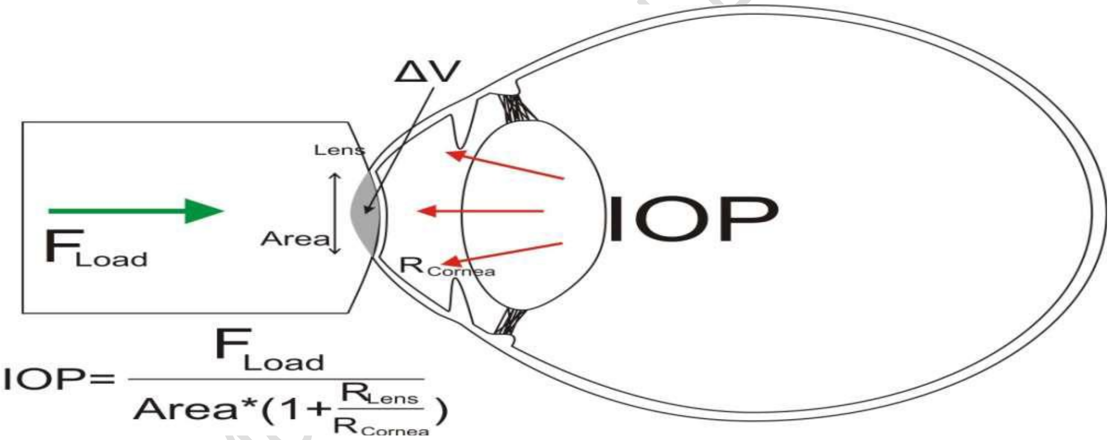
The pressure in normal eyes ranges from (12 –23) mm.Hg



Measuring the eye pressure :

1- By (feel)the physician estimate the pressure inside the eye by (feel) as they pressed on the eye with their fingertips

2- Tonometers .



An instrument is used to measure intraocular pressure(IOP).

Pressure in the Digestive System

- Opening through the body
- Over 6 m
- Closed at the lower end and has several restrictions
- Valves and sphincters permit unidirectional flow of food

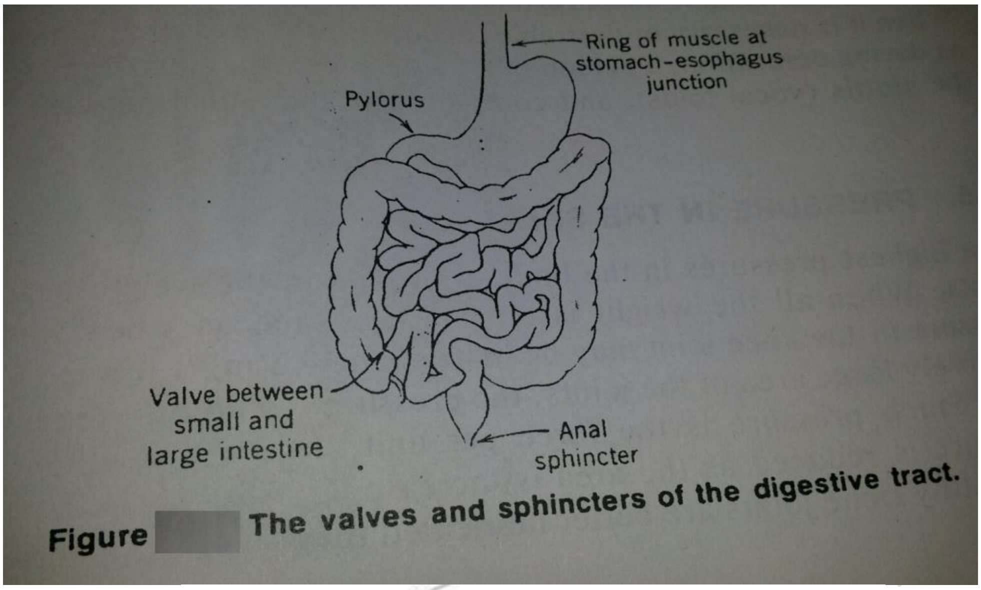
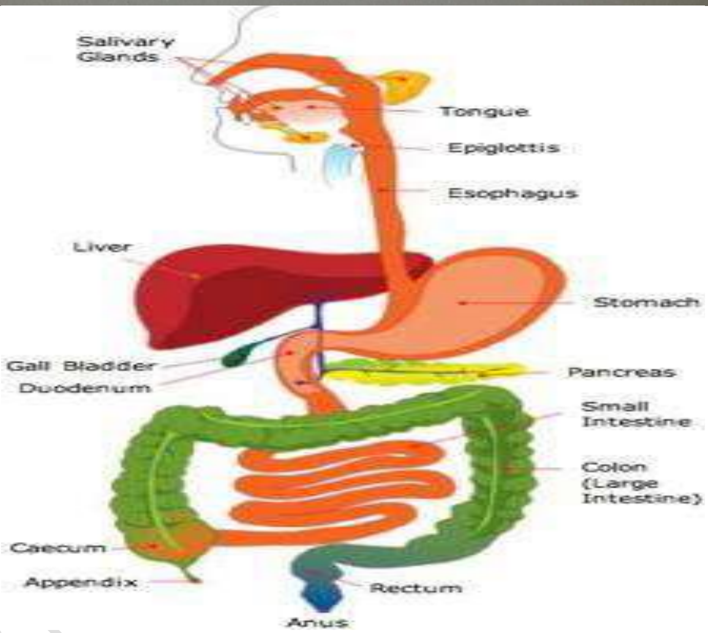


Figure The valves and sphincters of the digestive tract.



Pressure in the *gastrointestinal* (GI) system

- Greater than atmospheric pressure in most parts
- Esophagus pressure is usually less than atmospheric pressure
- Pressure in the *stomach*

1. Eating increases the pressure in the stomach slowly due to increased volume
2. Air swallowed during eating increases the pressure in the stomach →burping or belching

- Pressure in the *gut*

1. Bacterial action generates gas (flatus) →increase gut pressure
2. Belts, girdles, flying, or swimming →affect gut pressure

Pylorus: valve

- Prevents the flow of food back into the stomach from the small intestine

- Blockage in the small or large intestine →high pressure between the blockage and the pylorus →blockage of blood flow to critical organs →death

- ***Treatment***

1. Intubation: a hollow tube though the nose, stomach, and pylorus
2. Surgery in a pressure-controlled operating room

Pressure in skeleton:

The highest pressures in the body are found in the weight bearing bone (joints).

The pressure in the knee joint may be more than 10 atm.

P=F/A---------------- (1)

the surface area of a bone at the joint is greater than its area either above or below the joint. The larger area at the joint distributes the force thus reducing the pressure according to the equation 1.

Bone has adapted in another way to reduce pressure the finger bones are flat rather than cylindrical on the gripping side and the force is spread over a large surface this reducing tissues over the bones according to P=F/A .

Pressure in the urinary bladder :

The internal pressure in the bladder is due to the accumulation of the urine. The figure below shows the typical pressure - volume curve for the bladder, which stretches as the volume increase.

Urinary bladder

- Accumulation of urine →increase the urinary bladder pressure
- Pressure-volume curve of the bladder:

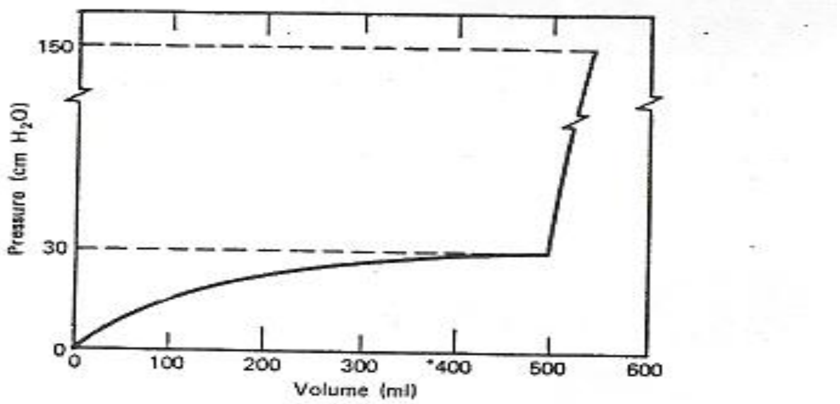


Figure The typical pressure-volume relationship in the urinary bladder (cystometrogram).

1. Volume ~ R^3
2. Pressure ~ R^2

3. Maximum volume before voiding is about 500 ml for adults
4. At about 30 cmH_2O, micturition reflex occurs →muscle contraction → pressure increase up to 150 cmH_2O →

-Voiding pressure
1. Normal: 20 ~ 40 cmH_2O
2. Prostatic obstruction: over 100 cmH_2O

The resulting sizable muscular contraction in the bladder wall produces a momentary pressure of up to 150 cmH_2O.

The pressure in the bladder can be measured:

1.By passing a catheter with a pressure sensor into the bladder through the urinary passage (urethra).

2.By a needle inserted through the wall of the abdomen directly into the bladder.

This technique gives information about the function of the exit valves that can not be obtained with the catheter technique.

The bladder pressure increases during coughing, straining, sitting up, also during pregnancy the weight of the fetus over the bladder increase the bladder pressure and causes frequent urination.

Normal voiding pressure is fairly low (20-40)cm H_2O but for Men who suffer from prostate obstruction of the urinary passage it may be over 100cmH_2O.

Urinary bladder pressure measurements
1. Catheter with a pressure sensor through the urinary passage (urethra)
2. Direct cystometry using a needle gives a function of the sphincters

Urinary incontinence
1. Coughing, laughing, straining
2. Pregnancy, stress

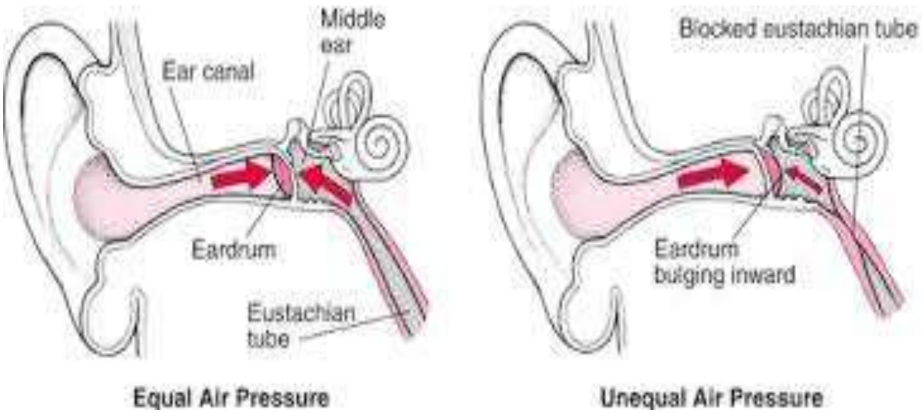
Pressure Effects in the Diving:

For a fixed quantity of gas at a fixed temperature the product of the absolute and volume is constant.(PV=constant)

$P_1 V_1 = P_2 V_2$ (*Boyle s law*)

That is , if the absolute pressure is double, the volume is halved.

The middle ear is one of the air cavities that exist within the body. For comfort the pressure in the middle ear should be equal to the pressure on the outside of the eardrum.



Pressure effect while diving

$P_{\text{middle ear}} = P_{\text{outside the eardrum}}$, this equalization is produced by air flowing through the Eustachian tube , which is usually closed except during swallowing , chewing ,and yawning.

-When diving many people have difficulty obtaining pressure equalization and feel pressure on their ears.

-(120mmHg) across the eardrum, which can occur in about 1.7 m of water, can cause the damage (rupture) to the eardrum.

One method of equalization used by a diver is to raise the pressure in the mouth by holding the nose and trying to blow out.

<u>The pressure in the lung:-</u>

$P_{\text{in the lung at any depth}} > P_{\text{in the lung at sea level}}$

This means that the air in the lung is denser under water and that the partial pressures of all the air components are proportionately higher .

1- The higher partial pressure of O_2 causes more O_2 molecules to be transformed into the blood , and oxygen poisoning results if the partial pressure of O_2 gets high .Partial pressure of O_2 is (0.8 atm) and absolute air pressure is (4 atm) at depth of (30 m).
2- Breathing air at a depth of (30m) is also dangerous because it may result in excess N_2 in the blood and tissues ,there is a possibility of having :
   - Nitrogen narcosis (intoxication effect).
   - The bends or decompression sickness (a scant problem).

*O_2 is attached to red blood cells , while N_2 is dissolved in the blood and tissues .

<u>Hyperbaric Oxygen Therapy (HOT):-</u>

The body normally lives in an atmosphere that is about one fifth O_2 and four – fifth N_2. In some medical situations it is beneficial to increase the proportion of O_2 in order to provide more O_2 to the tissue.

1- Gas gangrene :-

   The bacillus causes gas gangrene then its treated with (HOT) . That is due to bacillus cannot survive in the presence of oxygen (O_2).

2- Carbon Monoxide poisoning :-

   - The red blood cells cannot carry O_2 to the tissues because the carbon monoxide fasters to the hemoglobin at the places normally used by O_2.
   - Normally the amount of O_2 dissolved in the blood is about 2% of that carried on the red blood cells.
   - By using the (HOT) technique , the partial pressure of O_2can be increased by a factor of 15, permitting enough O_2 to be dissolved to fill the body's need .

3- Treatment of cancer :-

   (HOT) with radiation is given to the patient in transparent plastic tank. The theory was that more oxygen would make the poorly oxygenated radiation-resistant cell in the center of the tumor more susceptible to radiation damage .